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Wahl et al.

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(54) **GOLF CLUB HEAD HAVING A COMPOSITE FACE INSERT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 683 days.

(21) Appl. No.: **12/655,082**

(22) Filed: **Dec. 21, 2009**

(65) **Prior Publication Data**

US 2010/0151960 A1 Jun. 17, 2010

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/589,486, filed on Oct. 22, 2009, now Pat. No. 7,871,340, which is a continuation of application No. 11/895,195, filed on Aug. 21, 2007, now Pat. No. 7,628,712, which is a continuation of application No. 10/442,348, filed on May 21, 2003, now Pat. No. 7,267,620.

(51) **Int. Cl.**
A63B 53/04 (2006.01)

(52) **U.S. Cl.**
USPC **473/342**; 473/345; 473/350

(58) **Field of Classification Search**
USPC 473/324–350
See application file for complete search history.

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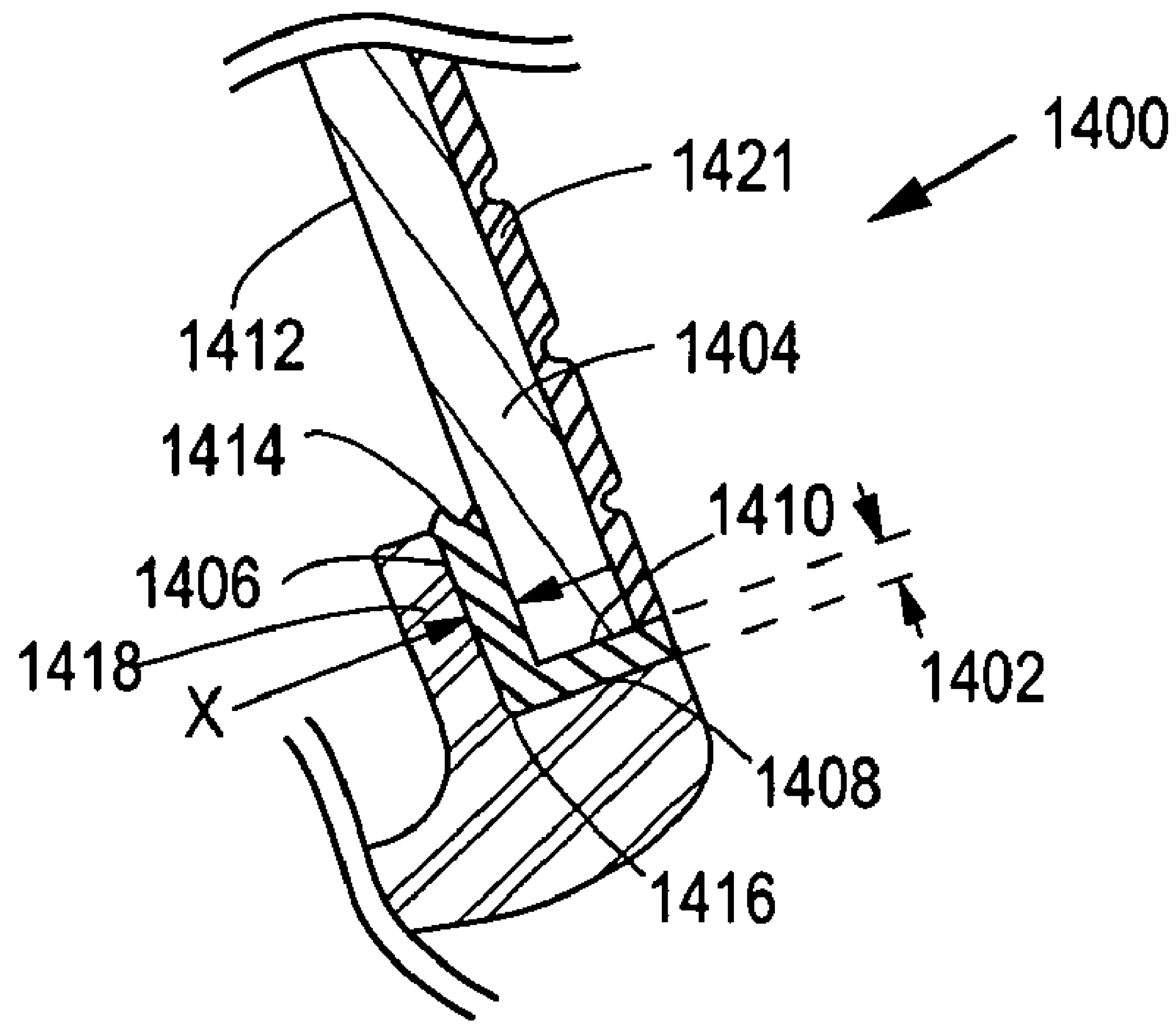
(57) **ABSTRACT**

A golf club head having a composite face insert attached to a metallic body is provided. The club head preferably has a volume of at least 200 cc and provides superior durability and club performance. The face insert includes prepreg plies having a fiber areal weight (FAW) of less than 100 g/m^2. The face insert preferably has a thickness less than 4 mm and a mass at least 10 grams less than an insert of equivalent volume formed of the metallic material of the body of the club head. A metallic cap with a peripheral rim is also provided to protect the ends of the composite material of the face insert. Related methods of manufacturing and alternative materials are disclosed. The resin content of the prepreg plies can be controlled through management of the timing and environment in which the resultant prepreg plies are cured and soaked.

18 Claims, 13 Drawing Sheets



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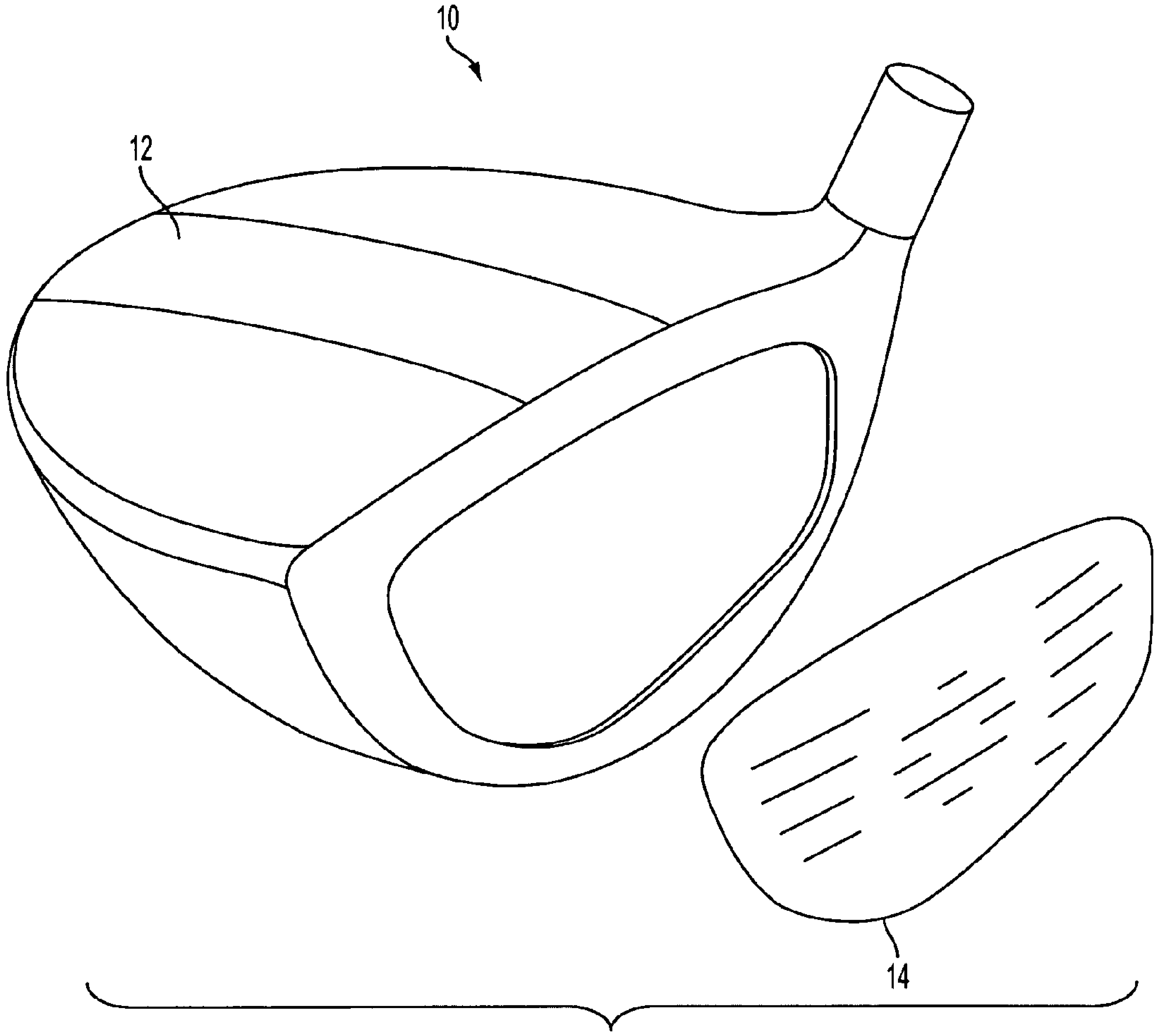

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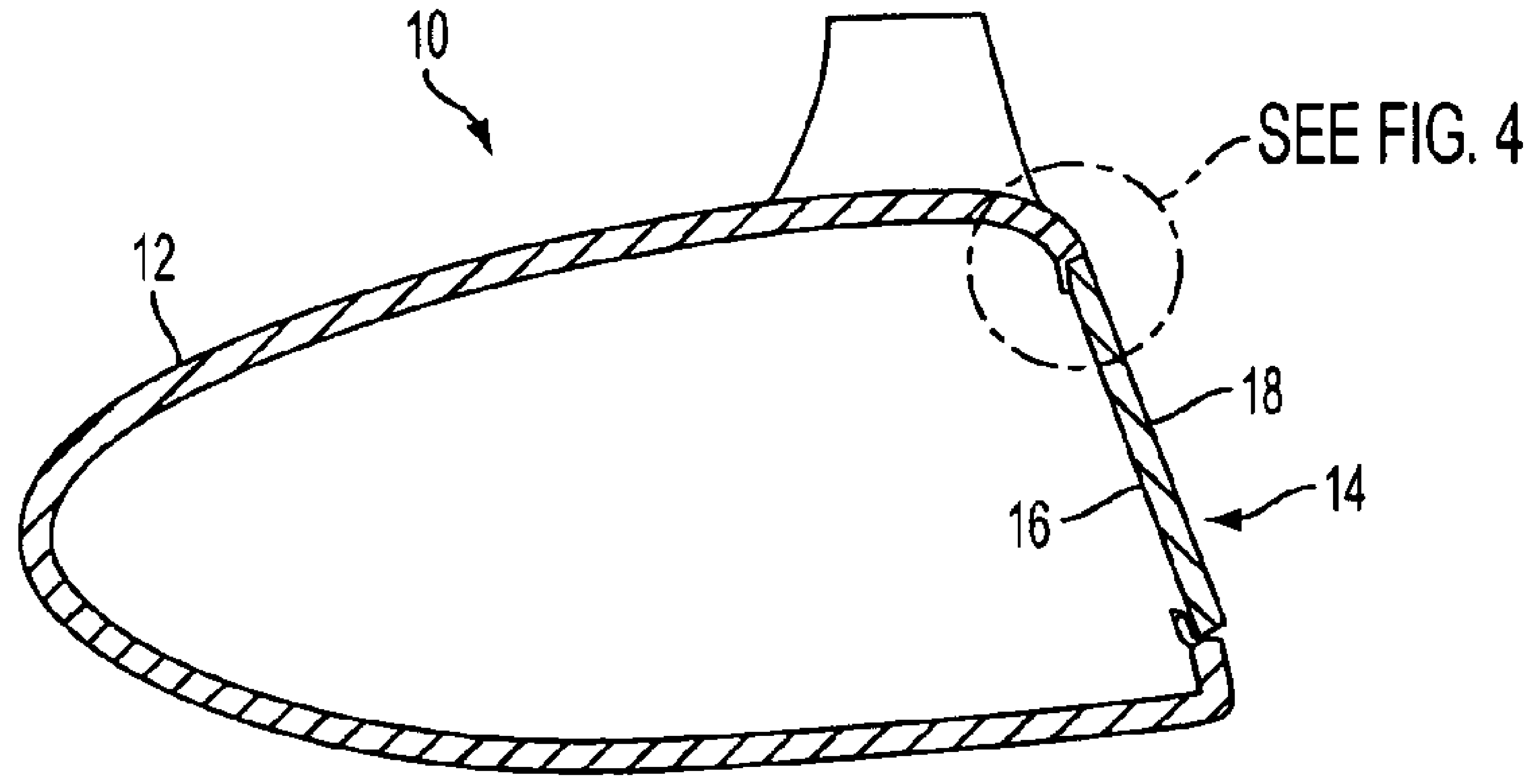

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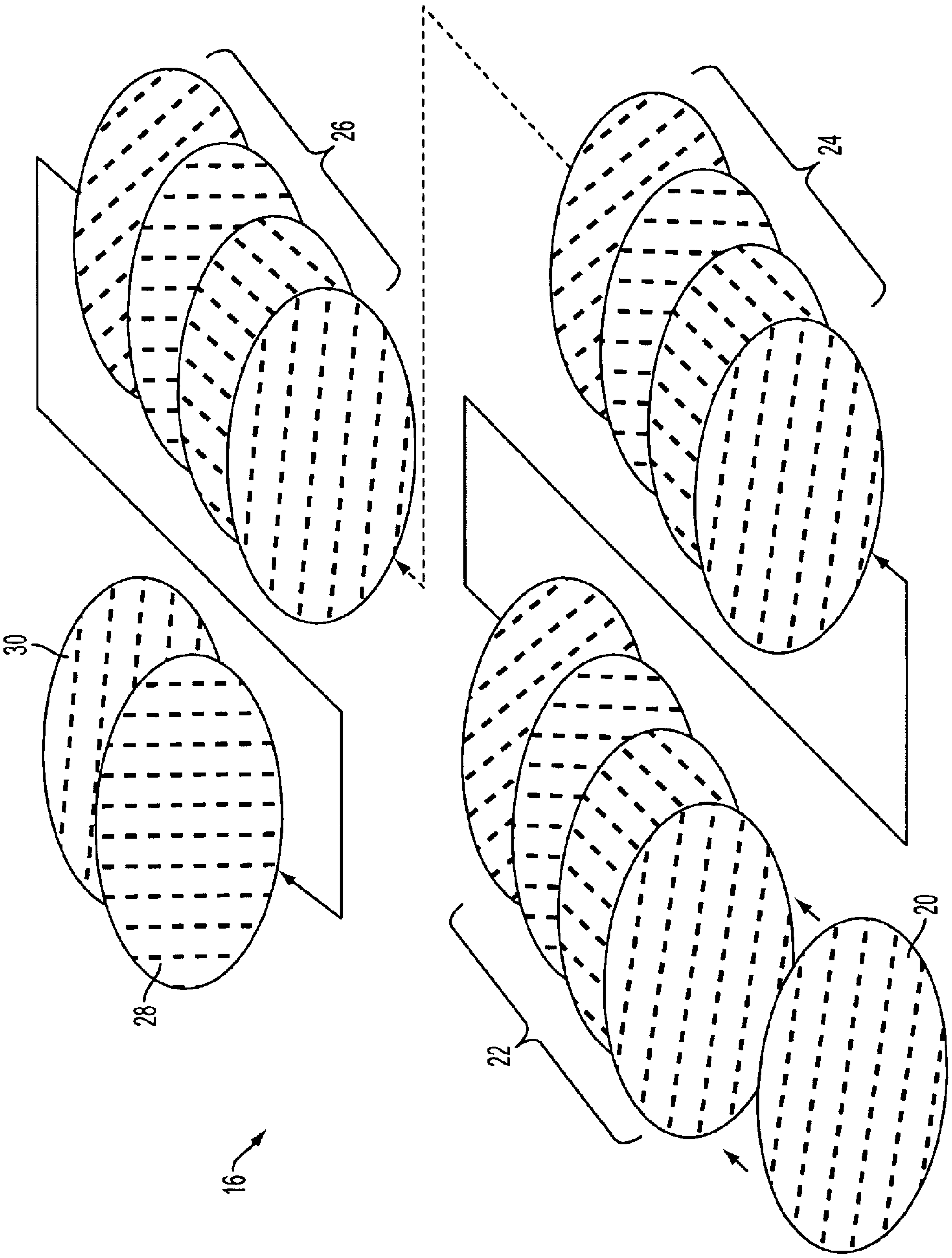

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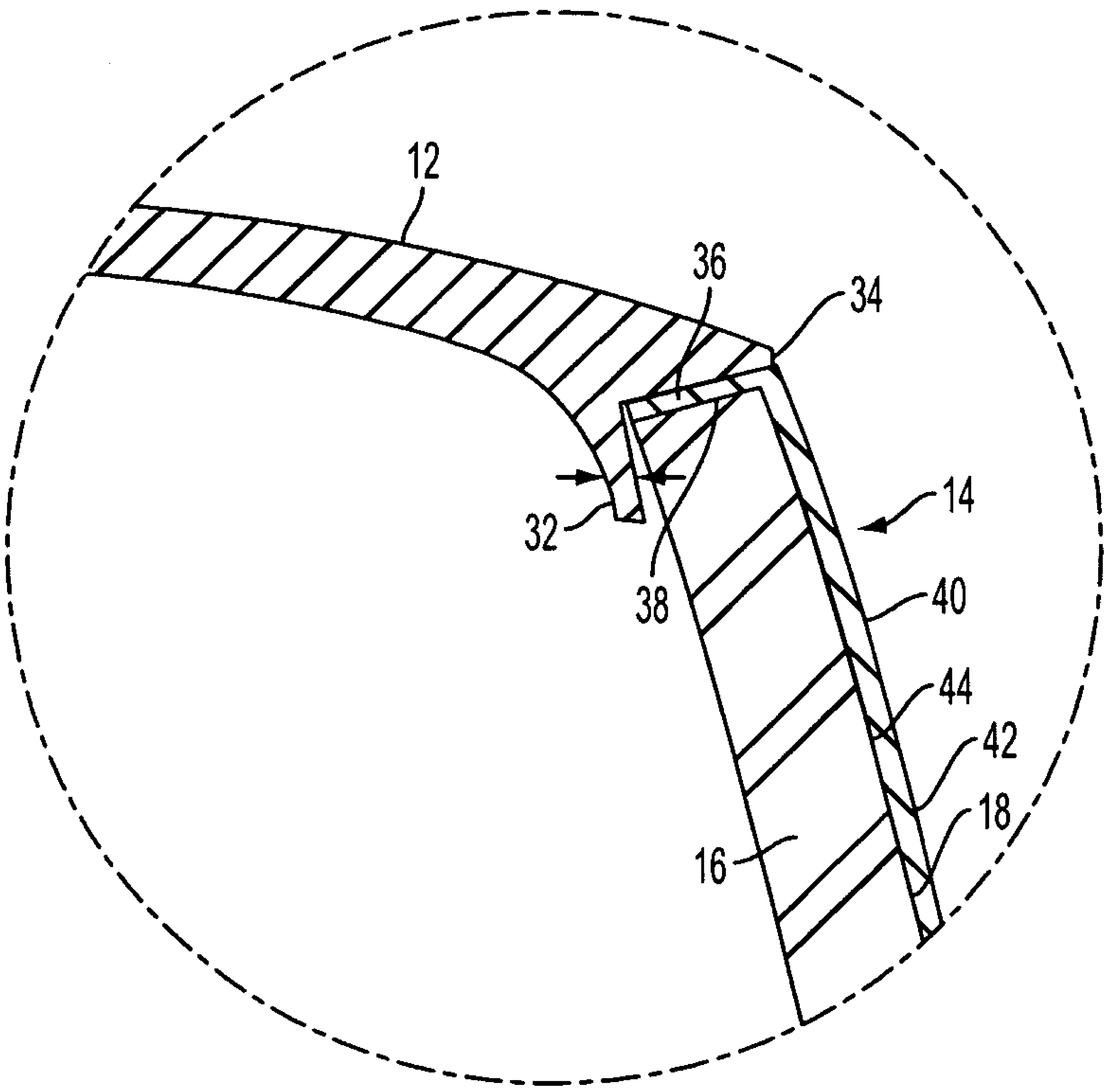

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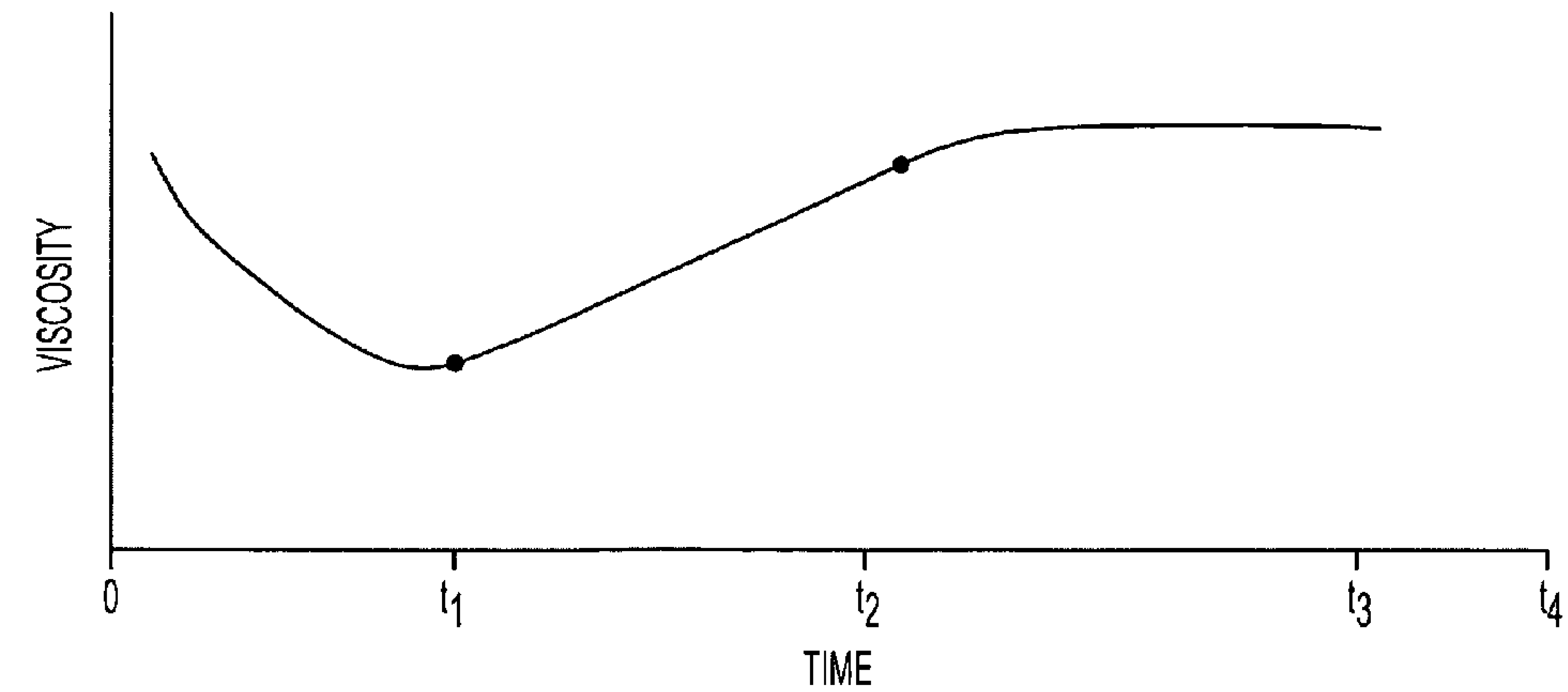

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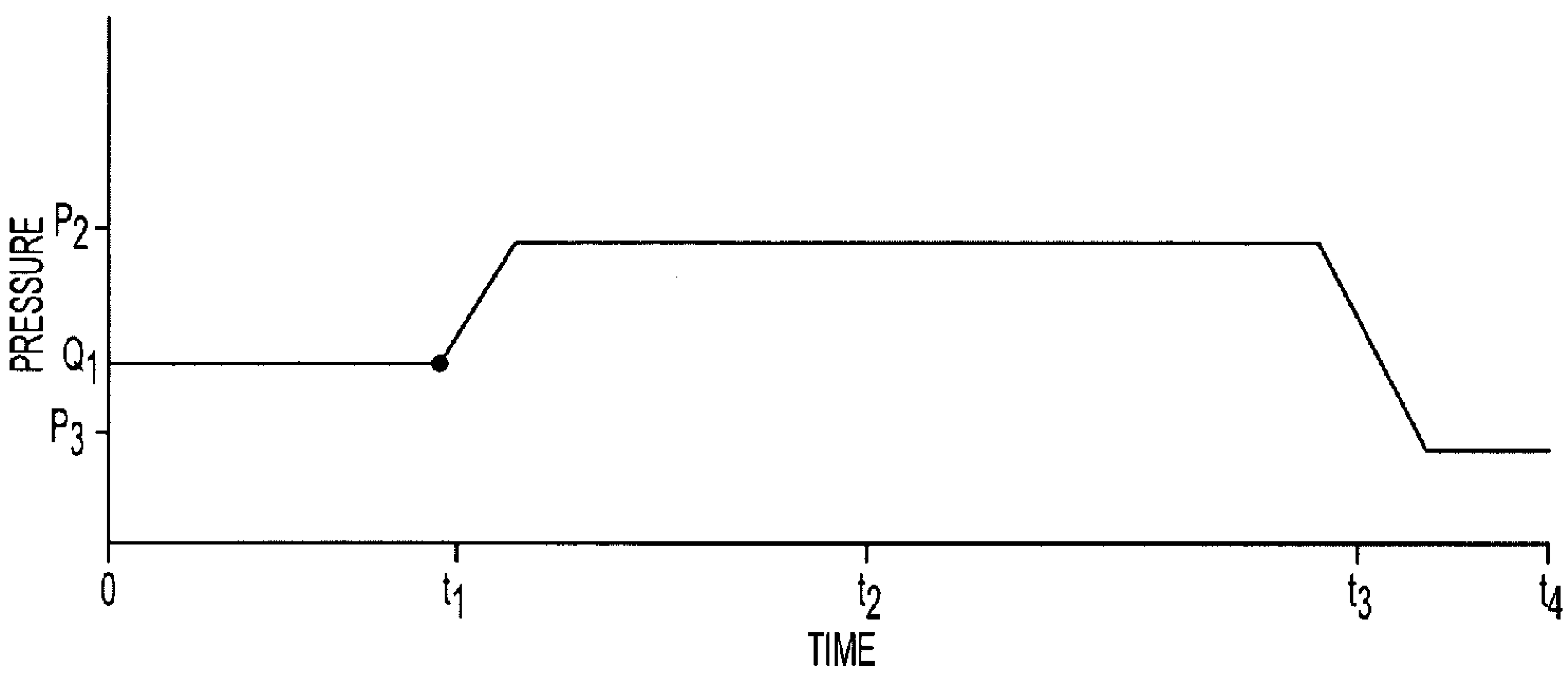

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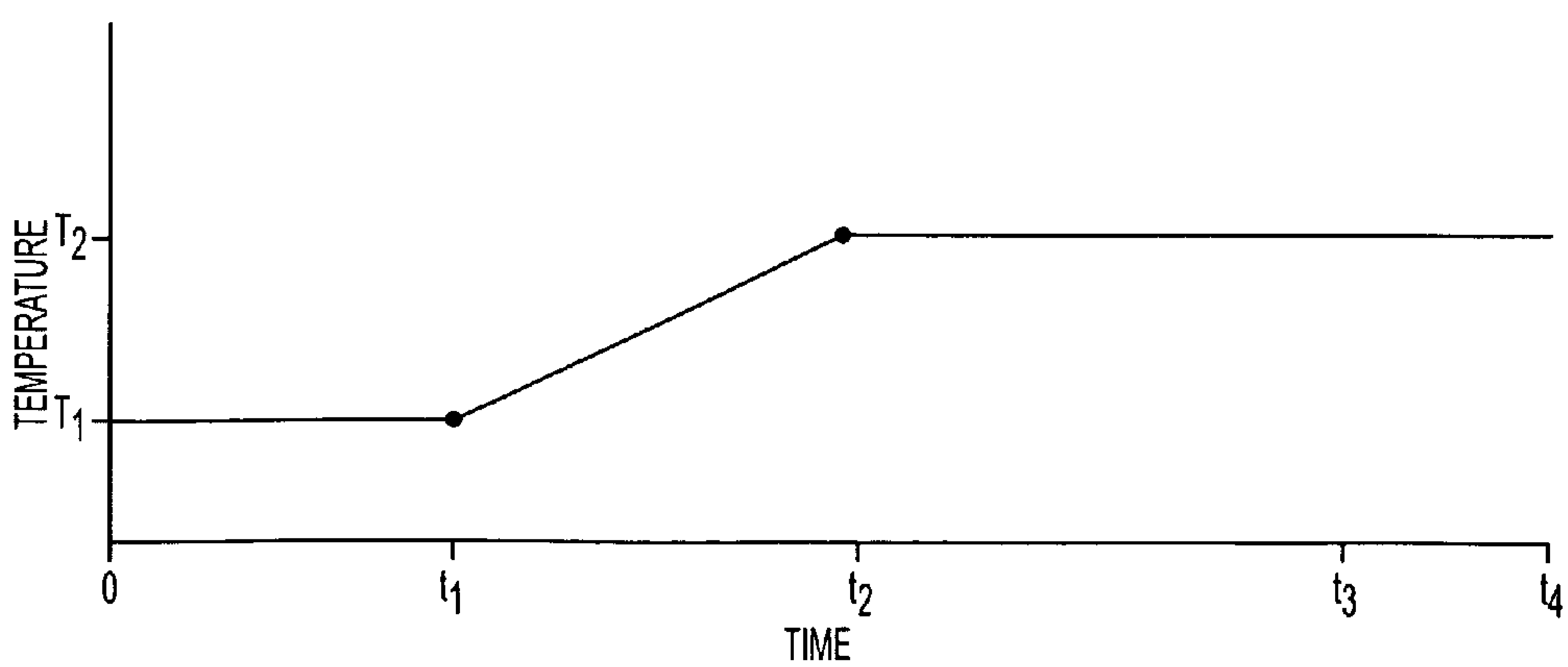

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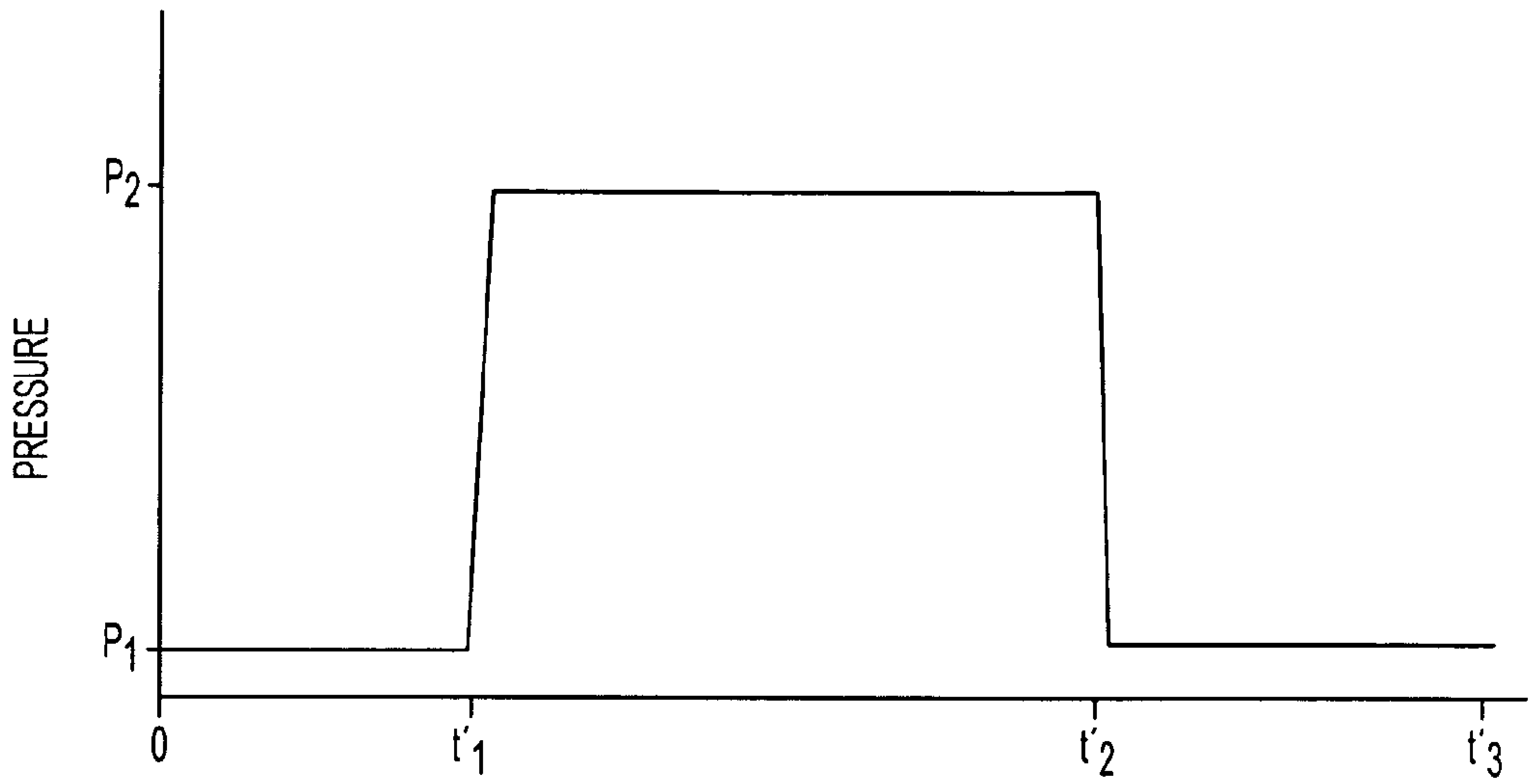

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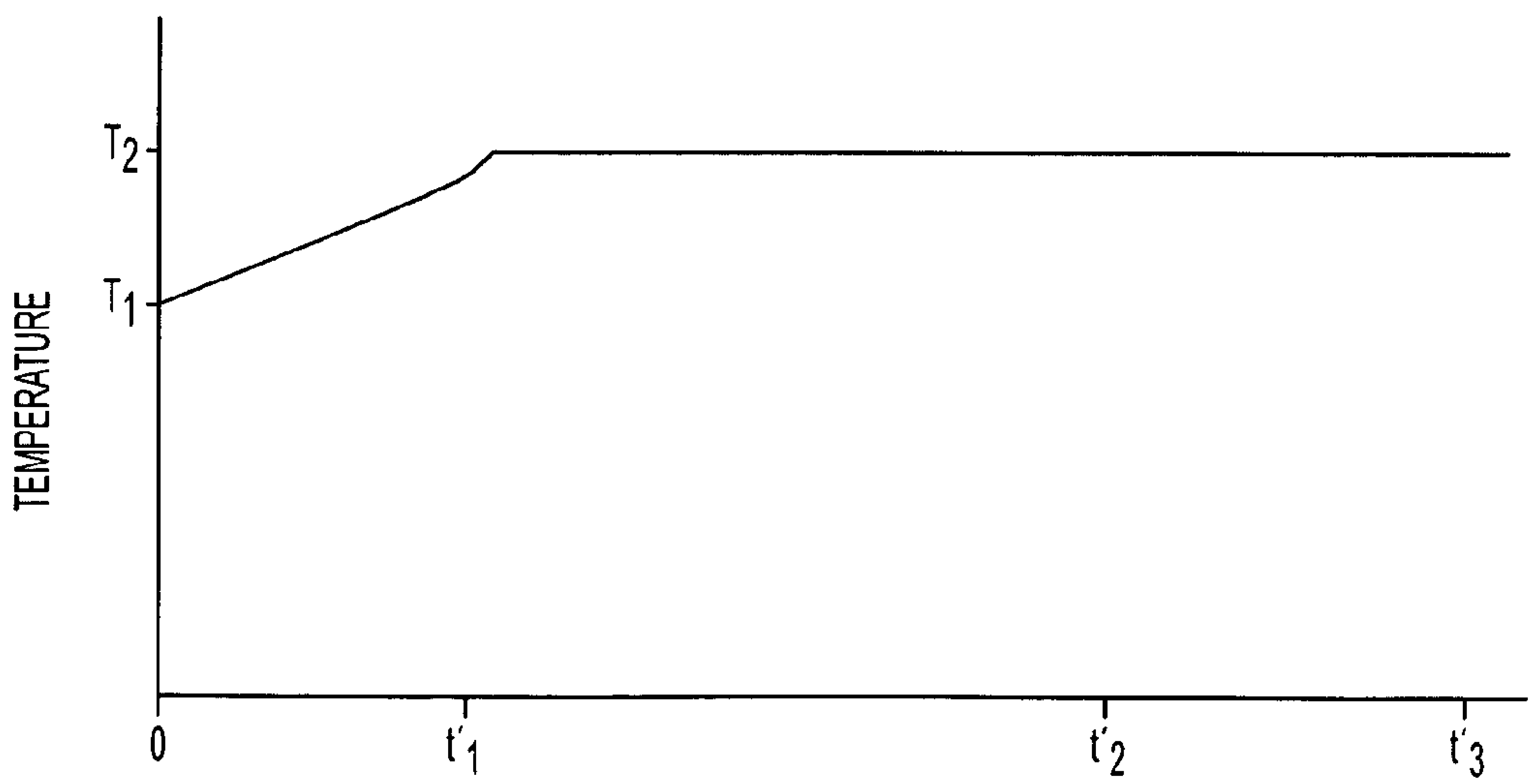

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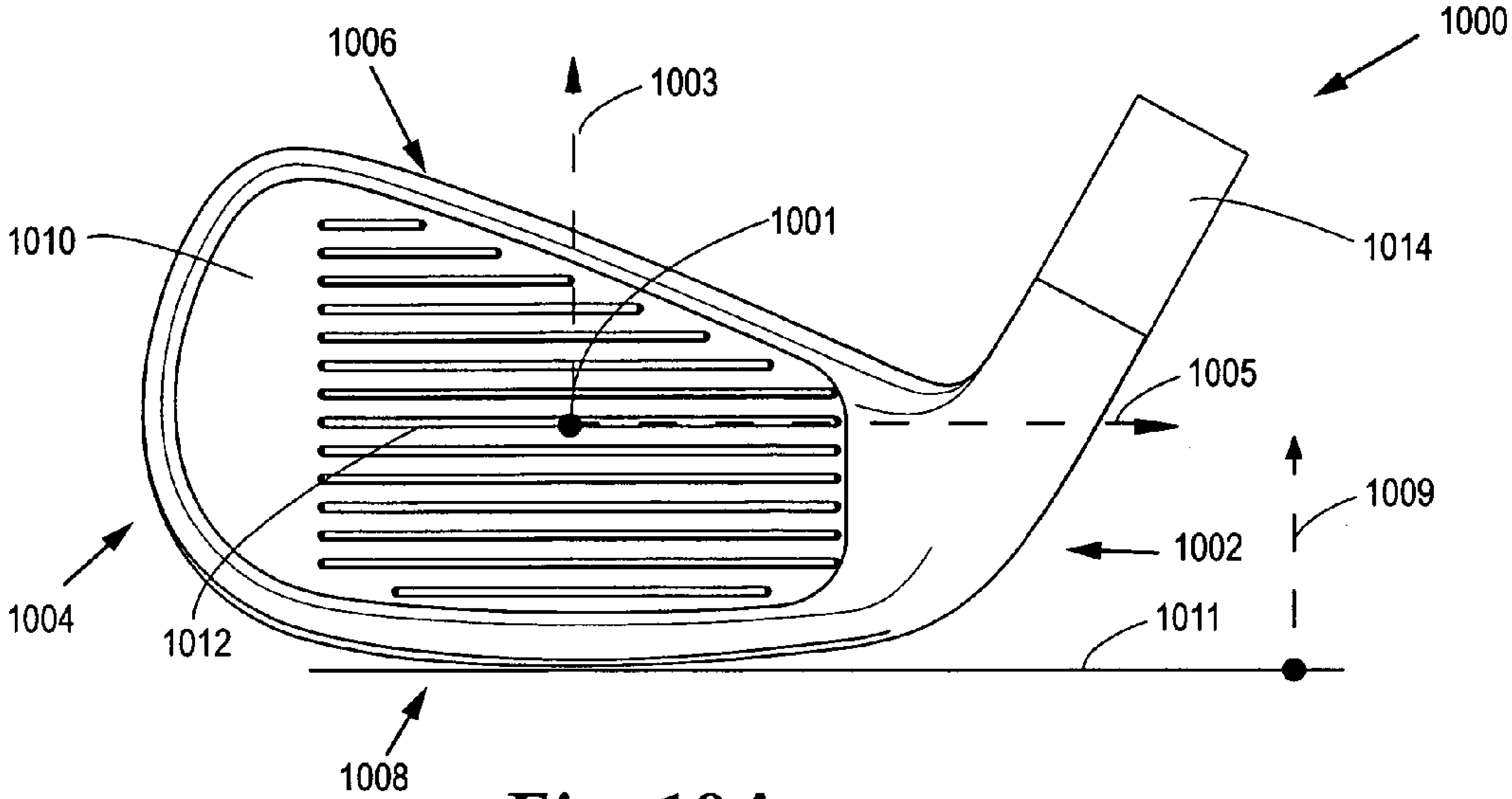

Fig. 10A

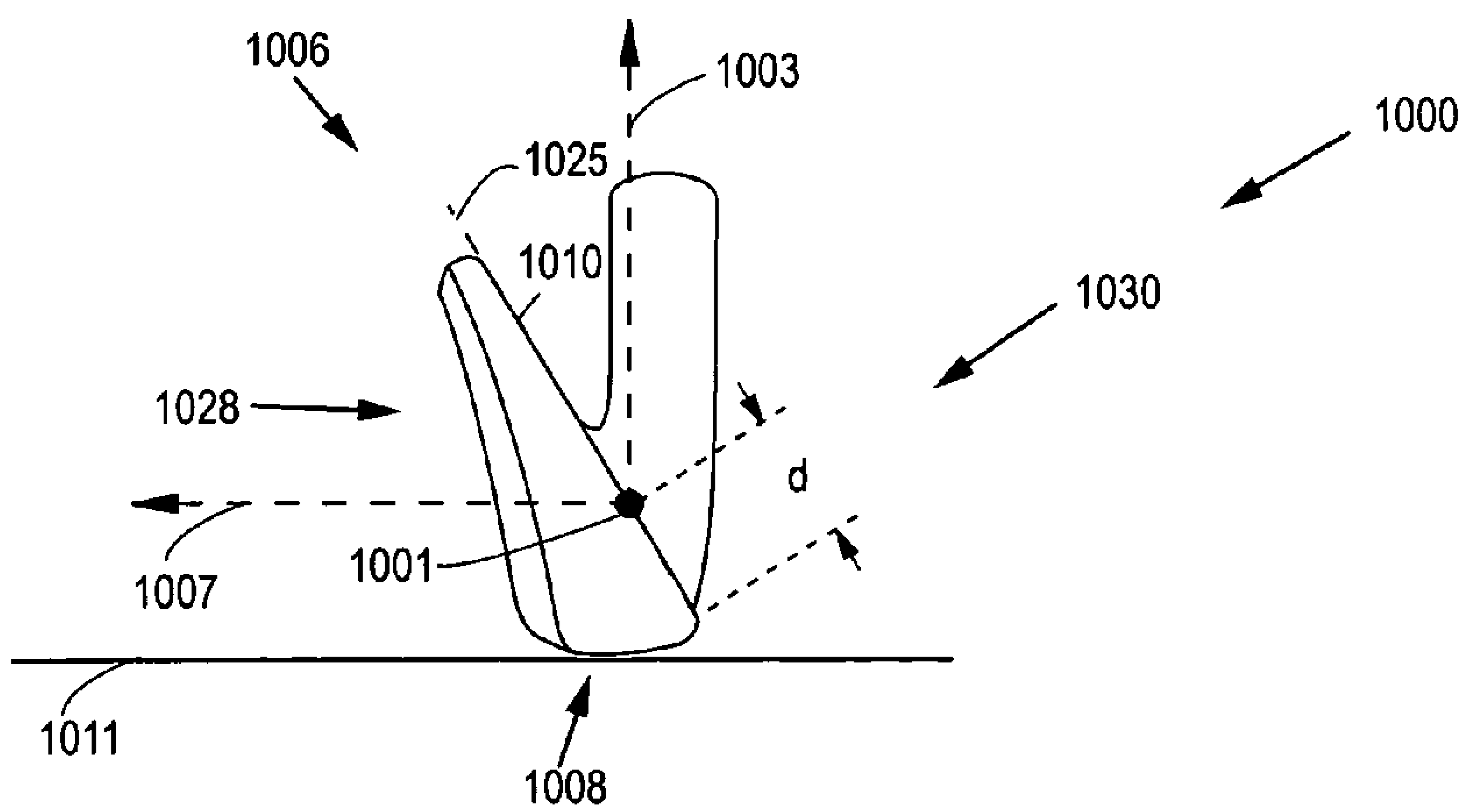

Fig. 10B

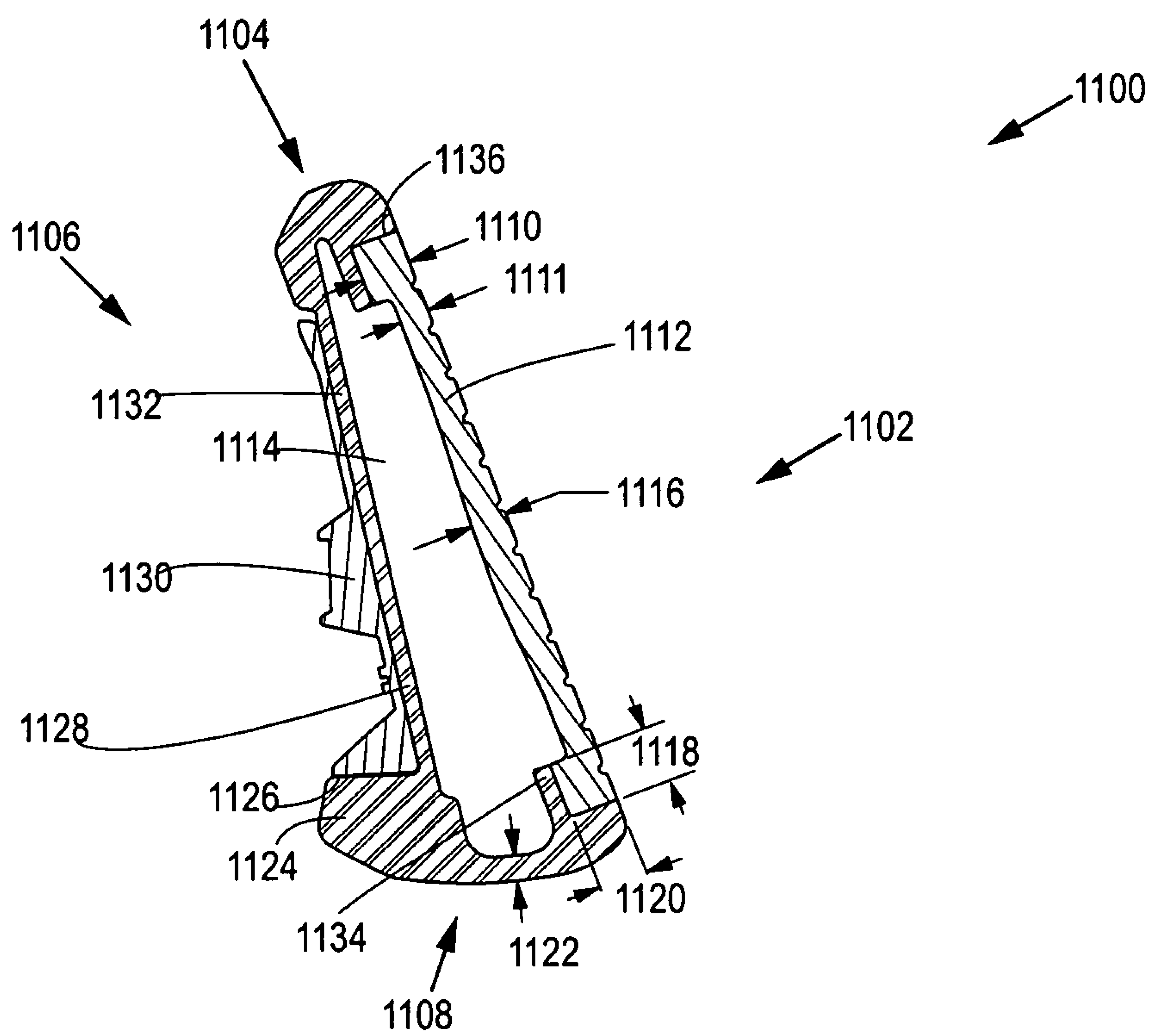
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Fig. 11

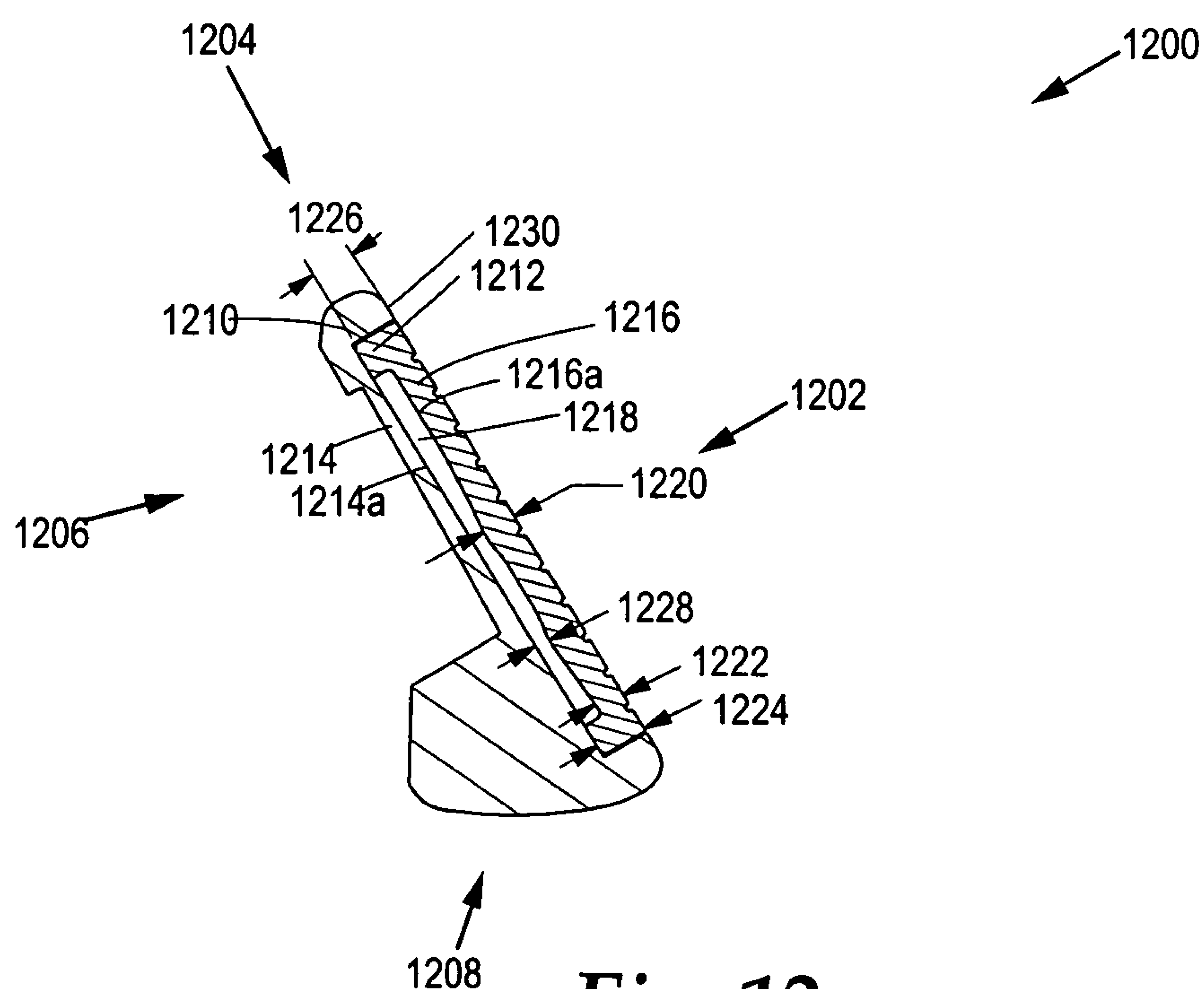
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Fig. 12

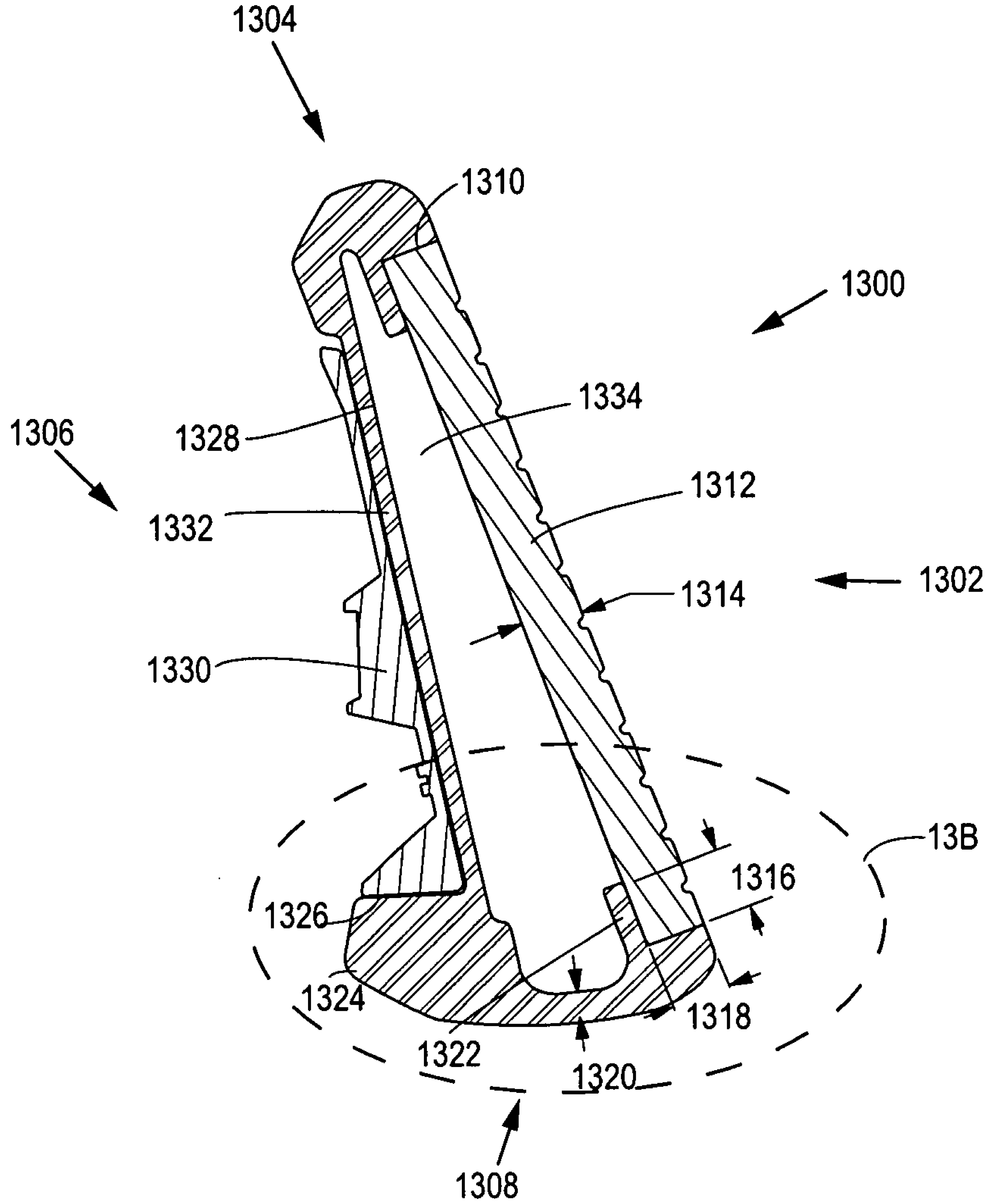


Fig. 13A

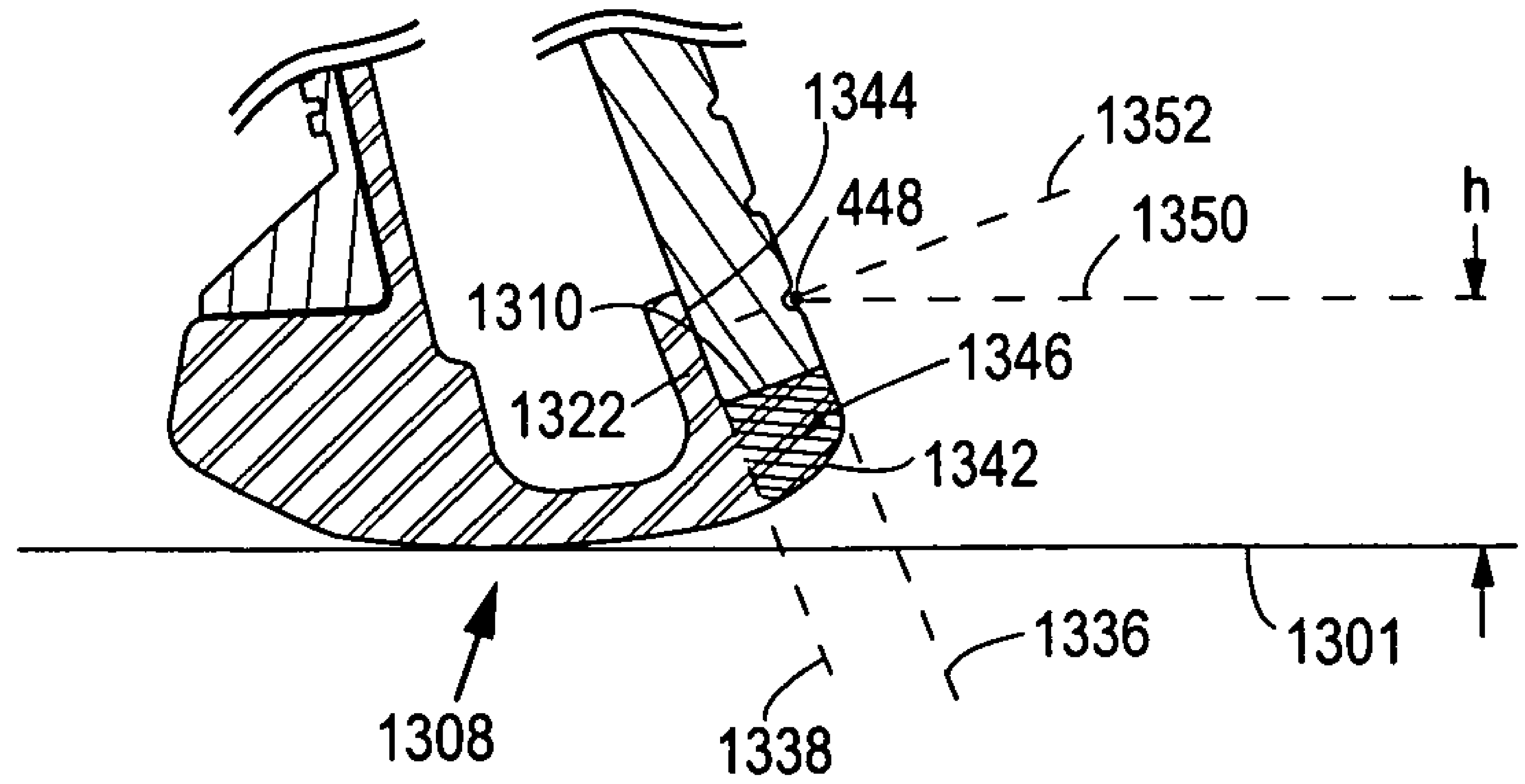


Fig. 13B

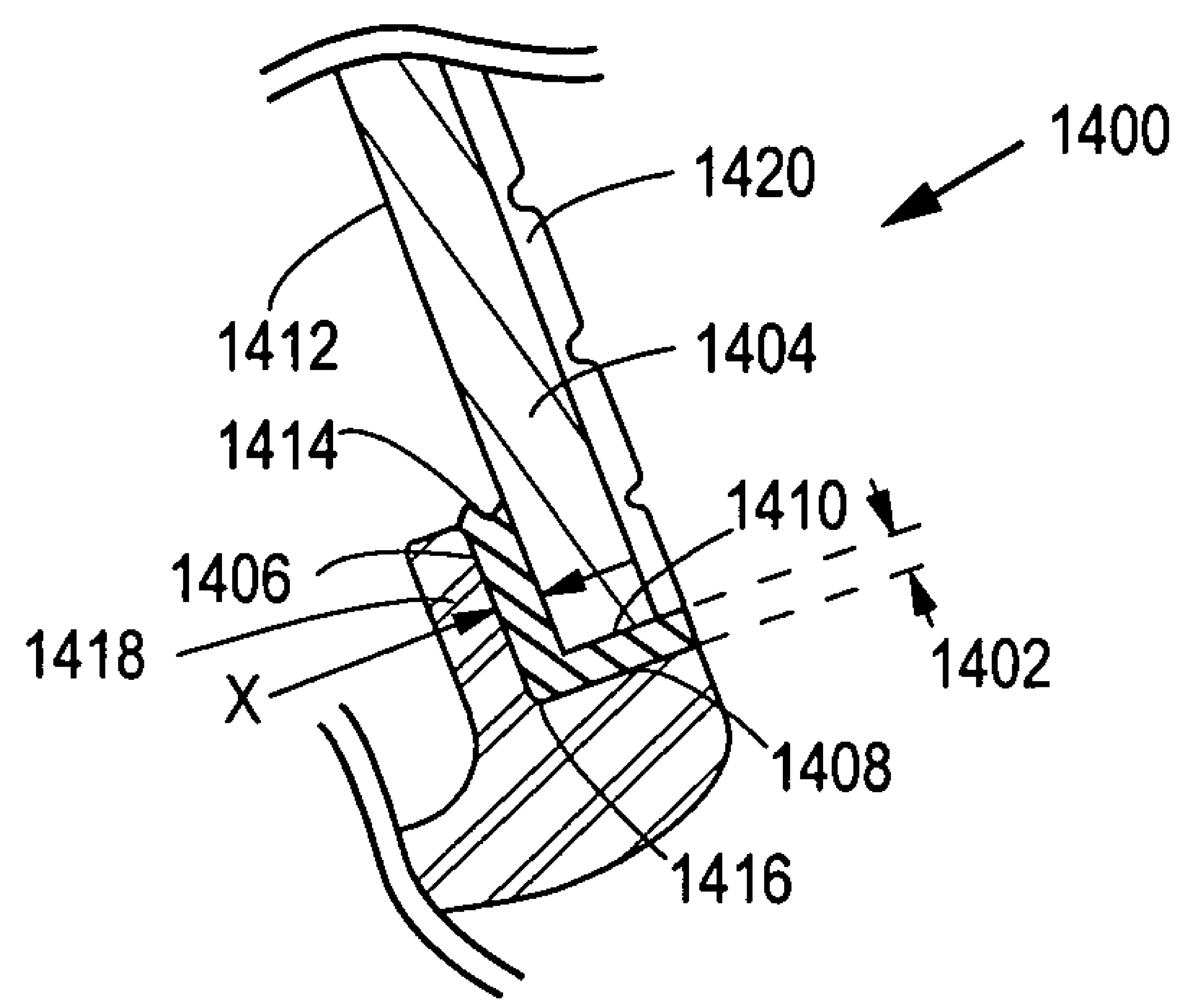


Fig. 14A

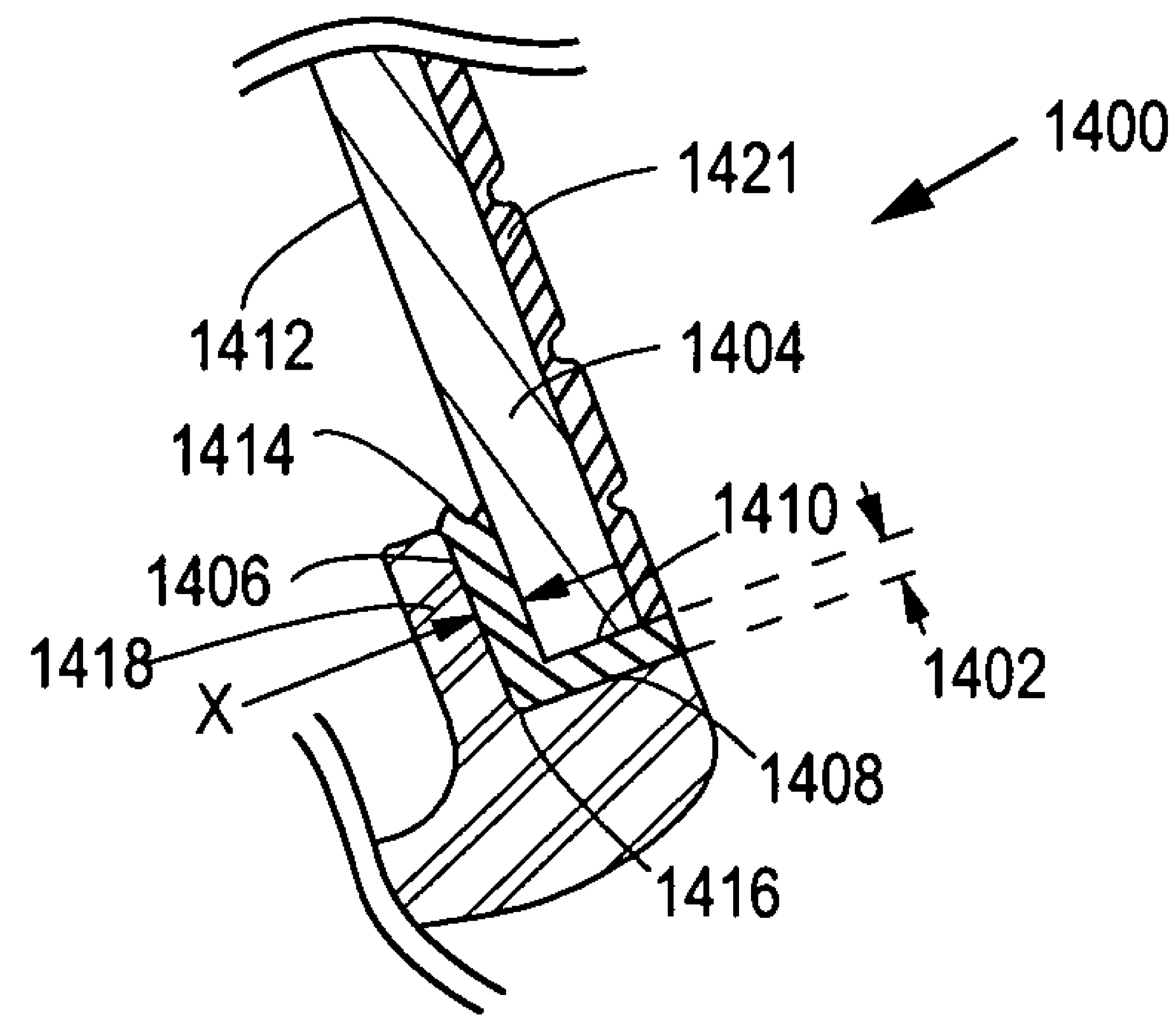
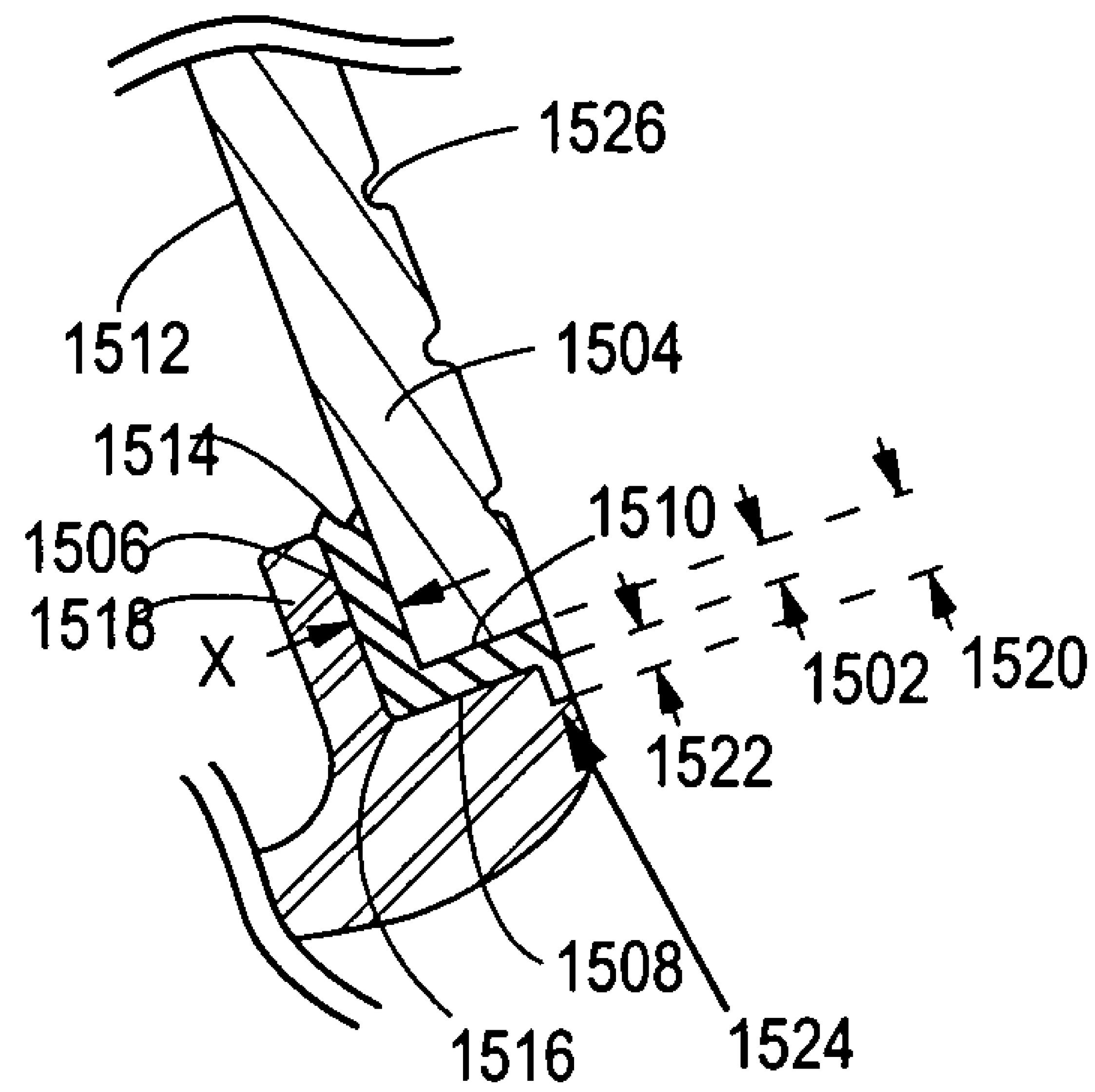


Fig. 14B



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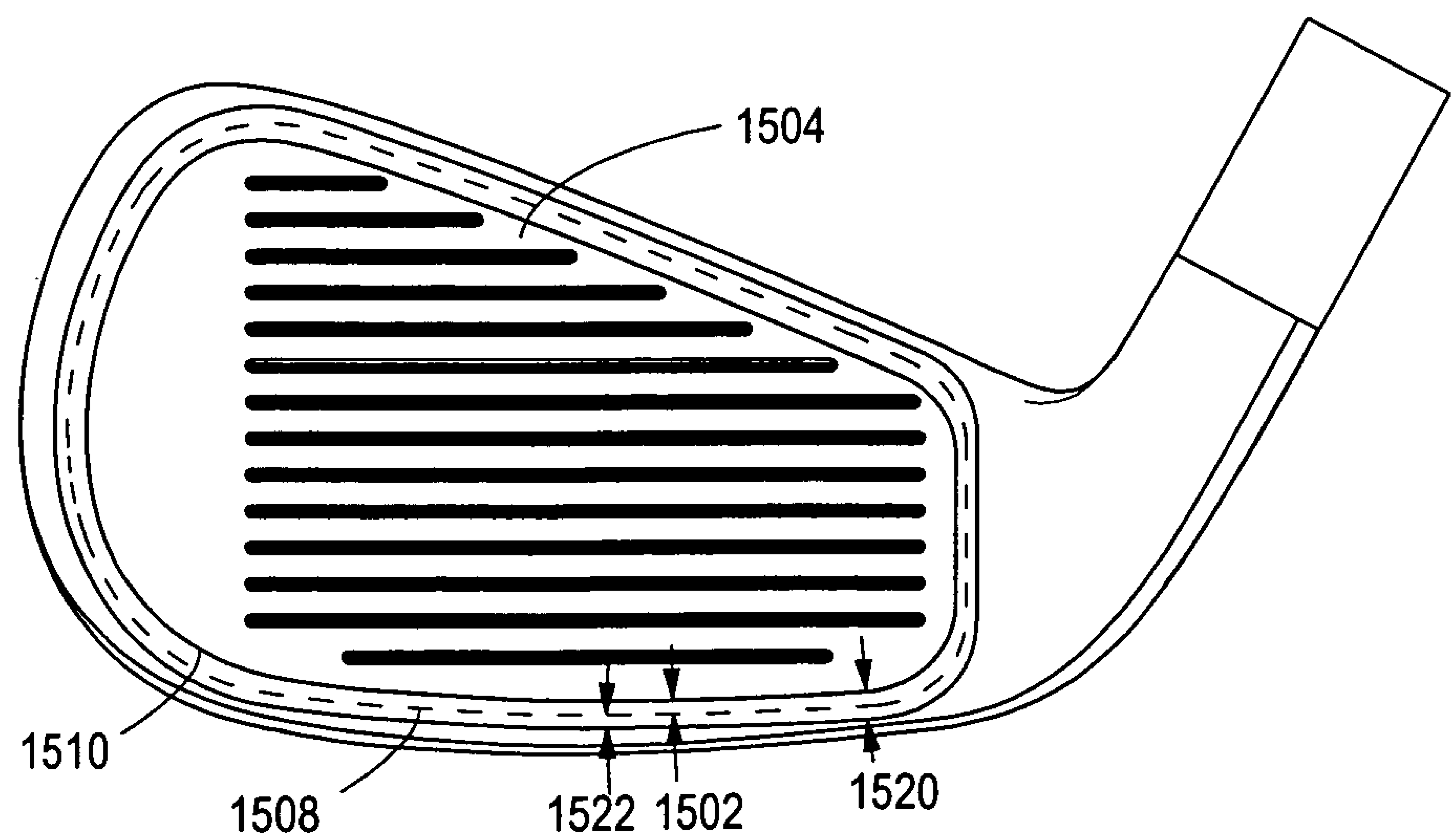

Fig. 15B

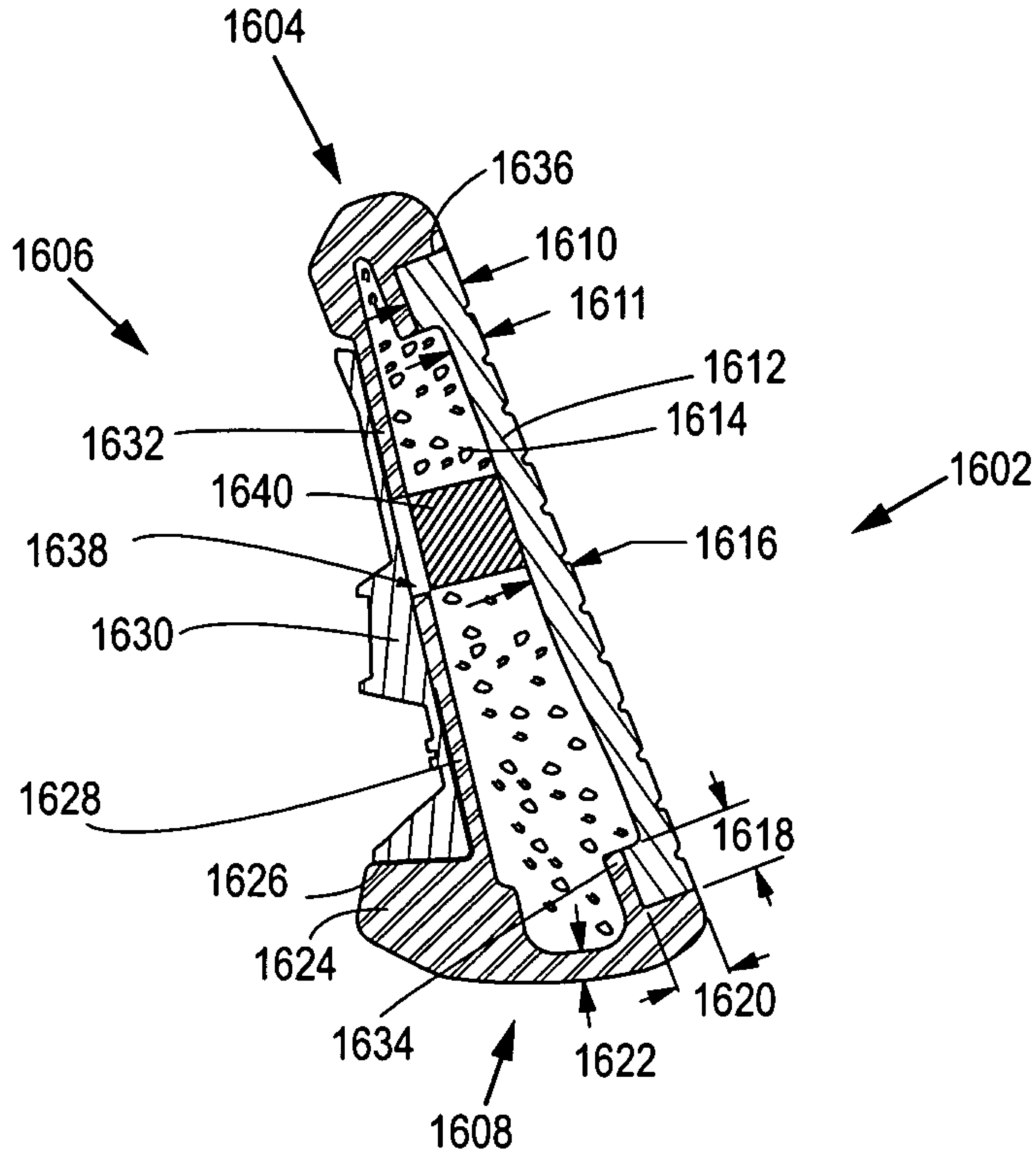
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Fig. 16

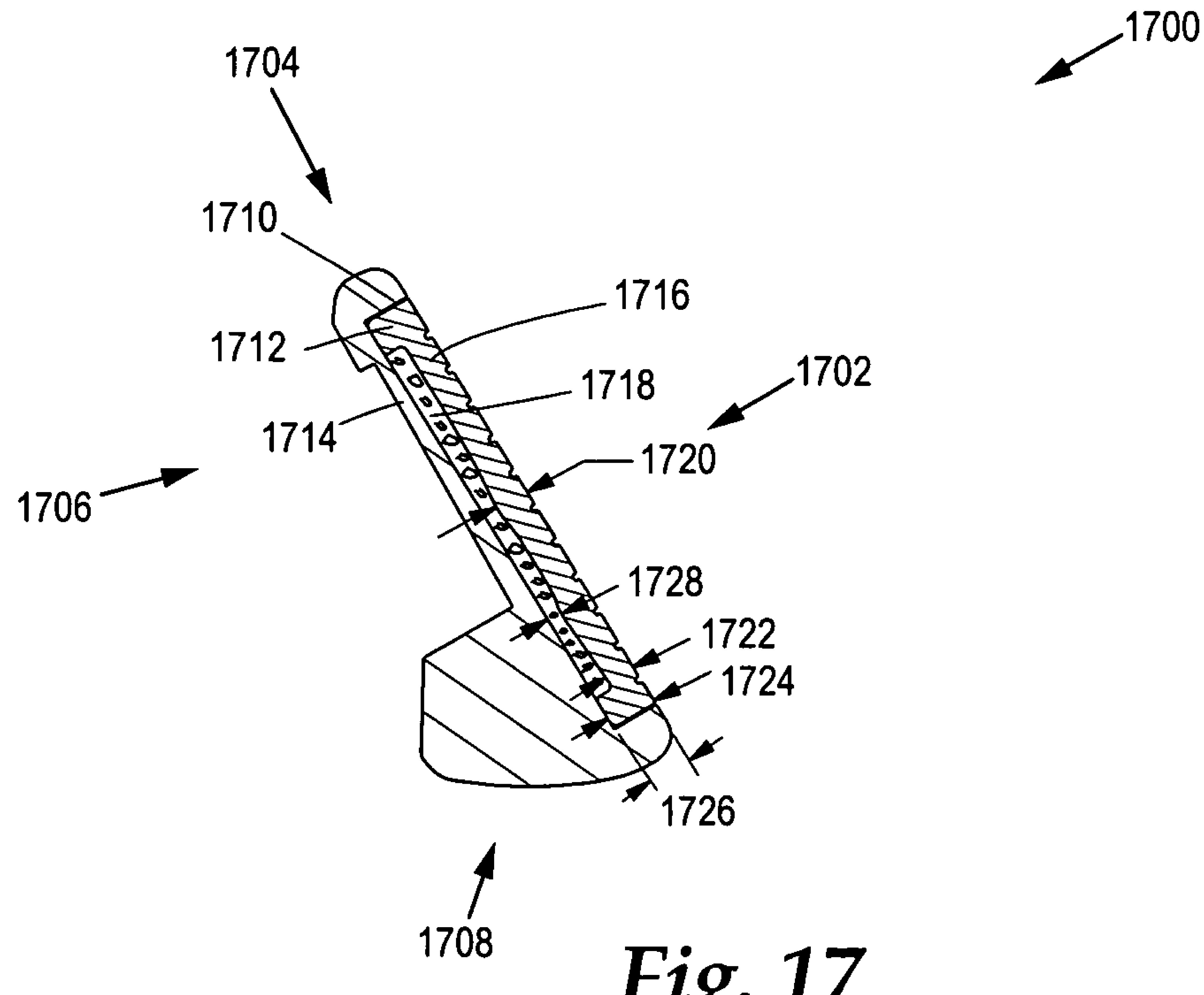
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Fig. 17

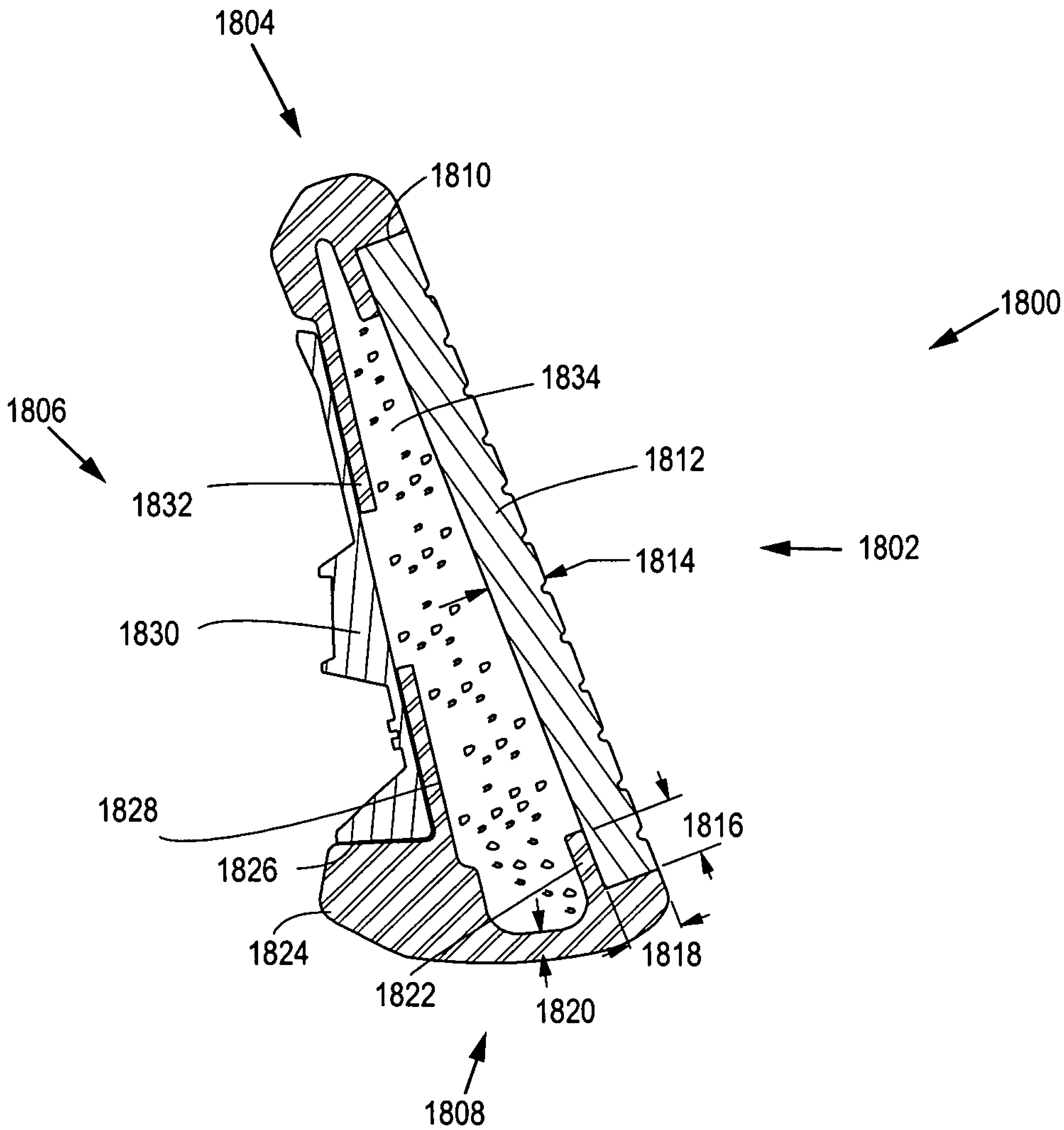
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Fig. 18

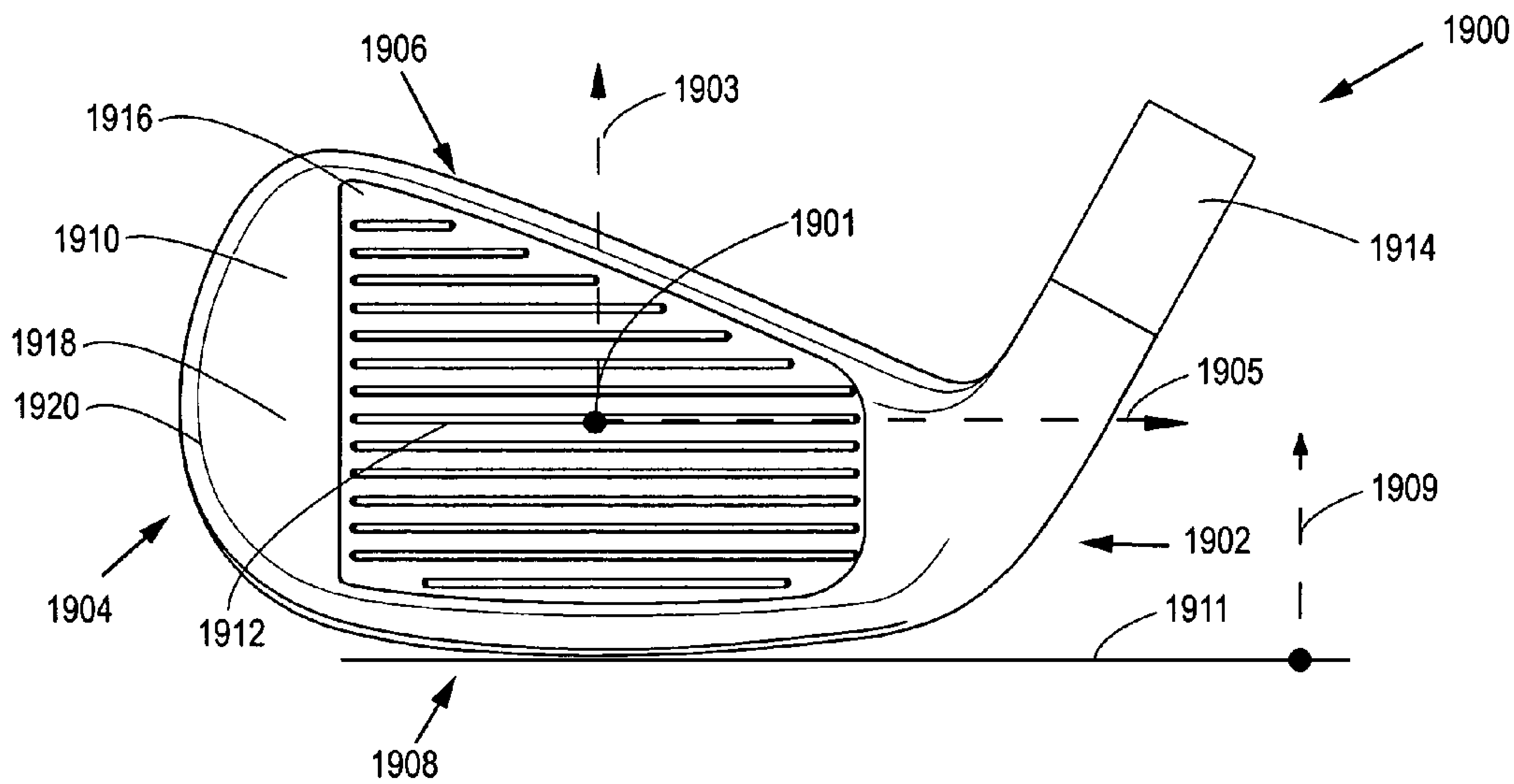
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Fig. 19

GOLF CLUB HEAD HAVING A COMPOSITE FACE INSERT

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 12/589,486, filed Oct. 22, 2009 now U.S. Pat. No. 7,871,340, which is a continuation of U.S. patent application Ser. No. 11/895,195, filed Aug. 21, 2007 (now U.S. Pat. No. 7,628,712), which is a continuation of U.S. patent application Ser. No. 10/442,348, filed May 21, 2003 (now U.S. Pat. No. 7,267,620), which are hereby incorporated herein by reference.

BACKGROUND

The present invention relates generally to golf club heads and, more particularly, to a wood-type golf club head having a composite face insert.

Composite materials have long been recognized for combining many beneficial attributes of various types and are commonly used in golf club heads. Composite materials typically are less dense than other materials used in golf clubs. Thus, the use of composite materials allows for more leeway in how weight is distributed about the club. It is often desirable to locate club weight away from the striking face. Thus, attempts have been made to incorporate composite materials in the club face.

Although such attempts have been generally effective for weight reduction purposes, a number of shortfalls remain, such as durability, impact resistance and overall club performance. For example, prior composite club faces have often suffered from delamination, or peeling apart, of composite layers, greatly reducing the useable life of the club. Delamination is particularly a problem at interface regions between the composite material and other materials of the club head. Such problems have arisen even at relatively low impact levels, hit counts and in benign playing conditions. Attempts to resolve such problems often fail to provide satisfactory club performance, measured by factors such as coefficient of restitution (COR), particularly for wood-type club heads having a volume of at least 300 cc. It should, therefore, be appreciated that there exists a need for a wood-type golf club head having composite material at the club face that is durable, can endure high level impacts and yet provide superior club performance. The present invention fulfills this need and others.

It should, therefore, be appreciated that there exists a need for a wood-type golf club head and an iron-type golf club head having composite material at the club face that is durable, can endure high level impacts and yet provide superior club performance. The present invention fulfills this need and others.

SUMMARY

The invention provides a golf club head having a lightweight face insert attached to a body that is at least partly formed of a metallic material, providing superior durability and club performance. To that end, the face insert comprises prepreg plies having a fiber areal weight (FAW) of less than 100 g/m^2. The body preferably forms a volume of at least 200 cc. The face insert preferably has a thickness less than 4 mm and has a mass at least 10 grams less than an insert of equivalent volume formed of the metallic material of the body of the

club head. The coefficient of restitution for the club head, measured in accordance to the United States Golf Association Rule 4-1a, is at least 0.79.

In a preferred embodiment of the invention, the face insert further includes a cap with a peripheral rim that is attached to a front surface of the composite region. Also preferably, the thickness of the composite region is about 4.5 mm or less and the metallic cap thickness is about 0.5 mm or less; more preferably the thickness of the composite region is about 3.5 mm or less and the metallic cap thickness is about 0.3 mm or less. The cap preferably comprises a titanium alloy. The face insert may alternatively comprise a layer of textured film co-cured with the plies of low FAW material, in which the layer of textured film forms a front surface of the face insert instead of the metallic cap. The layer of textured film preferably comprises nylon fabric. Without the metallic cap, the mass of the face insert is at least 15 grams less than an insert of equivalent volume formed of the metallic material of the body of the club head.

A preferred method of the present invention advantageously controls the resin content of the low fiber areal weight (FAW) composite material of the golf club face. The steps comprise:

- stacking and cutting a plurality of prepreg plies having a fiber areal weight (FAW) of less than 100 g/m^2 to form an uncured face insert having substantially a final desired shape, bulge and roll;
- placing the uncured face insert into a tool with an initial temperature T_1;
- curing the uncured face insert for about 5 minutes at a first pressure P_1 then initiating heating the tool to a set temperature T_2 greater than or equal to the initial temperature T_1 and curing another 15 minutes at a second pressure P_2 greater than the first pressure P_1, thus obtaining the cured face insert;
- continue forming the cured face insert at the set temperature and second pressure P_2 for about 30 minutes; and
- soaking the cured face insert for 5 minutes at a third pressure P_3 less than the second pressure P_2, such that the desired resin content is achieved.

Alternatively, the tool temperature may be immediately raised to a set temperature T_2 upon placement of the composite material therein, this temperature being held substantially constant over the soaking and curing phases. After an initial soaking time of about 5 minutes, the pressure is raised from a first pressure P_1 to a second pressure P_2 greater than the first pressure P_1. After an additional time of about 15 minutes, the pressure is reduced to about the same value as the first pressure for about another 20 minutes.

For purposes of summarizing the invention and the advantages achieved over the prior art, certain advantages of the invention have been described above. Of course, it is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

In one aspect of the present invention, an iron-type golf club a body having a heel portion, a sole portion, a toe portion, a top-line portion, a front portion, a rear portion, and a striking face is described. A cavity is defined by at least a rear surface of the striking face, an interior rear wall surface, and the sole portion. A composite face insert comprising prepreg plies having a fiber areal weight of less than 200 g/m^2 is also described. The face insert is attached at the front opening of the body and enclosing the front opening of the body. The thickness of the prepreg plies is within a range of about 1 mm to about 8 mm.

In another aspect of the present invention, an iron-type golf club body having a heel portion, a sole portion, a toe portion, a top-line portion, a front portion, a rear portion, and a striking face. A cavity is described that is defined by at least a rear surface of the striking face, an interior rear wall surface, and the sole portion. A composite face insert is described including prepreg plies having a fiber areal weight less than 100 g/m^2. The face insert is attached at the front opening of the body and enclosing the front opening of the body. The thickness of the prepreg plies is within a range of about 1 mm to about 8 mm. The golf club head having a coefficient of restitution of at least 0.79.

All of these embodiments are intended to be within the scope of the invention herein disclosed. These and other embodiments of the present invention will become readily apparent to those skilled in the art from the following detailed description of the preferred embodiments having reference to the attached figures, the invention not being limited to any particular preferred embodiment disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the following drawings in which:

FIG. **1** is an exploded view of a club head in accordance with the invention, depicting a composite face insert and a metallic body.

FIG. **2** is a cross-sectional view of the club head of FIG. **1**.

FIG. **3** is an exploded view of the composite region of the face insert of FIG. **1** showing the plies comprising the composite region.

FIG. **4** is a close-up view of area A-A of the club head of FIG. **2**, depicting a junction of the composite face insert and the body portion.

FIG. **5** is a graph depicting resin viscosity over time during the soaking and curing phases for a preferred method of forming the composite portion of the face insert of FIG. **1**.

FIG. **6** is a graph depicting pressure over time during the soaking and curing phases of forming the composite portion of the face insert, corresponding to FIG. **5**.

FIG. **7** is a graph depicting temperature over time during the soaking and curing phases of forming the composite portion of the insert, corresponding to FIG. **5**.

FIG. **8** is a graph depicting pressure over time during the soaking and curing phases of an alternative method of forming the composite portion of the insert of FIG. **1**.

FIG. **9** is a graph depicting temperature over time during the soaking and curing phases of forming the composite portion of the insert, corresponding to FIG. **8**.

FIG. **10**A illustrates a front view of an embodiment of a golf club head in an address position.

FIG. **10**B illustrates a toe-side view of the golf club head shown in FIG. **10**A.

FIG. **11** illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to one embodiment.

FIG. **12** illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to another embodiment.

FIG. **13**A illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to another embodiment.

FIG. **13**B illustrates a detailed view of a lower leading edge zone.

FIG. **14**A illustrates an adhesive interface between a face insert and club head body, according to one embodiment.

FIG. **14**B illustrates an adhesive interface between a face insert and club head body, according to another embodiment.

FIG. **15**A illustrates an engineering gap between a face insert and a club head body, according to another embodiment.

FIG. **15**B illustrates a front view of the golf club head shown in FIG. **15**A.

FIG. **16** illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to another embodiment.

FIG. **17** illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to another embodiment.

FIG. **18** illustrates a cross-sectional side view of a golf club head taken through an ideal impact location, according to another embodiment.

FIG. **19** illustrates a front view of a golf club head in an address position, according to another embodiment.

DETAILED DESCRIPTION

With reference to the illustrative drawings, and particularly FIGS. **1** and **2**, there is shown a golf club head **10** having a metallic body **12** and a face insert **14** comprising a composite region **16** and a metallic cap **18**. The face insert **14** is durable and yet lightweight. As a result, weight can be allocated to other areas of the club head **10**, enabling the club head's center of gravity to be desirably located farther from the striking face **40** and to further enhance the club head's moment of inertia. The body **12** includes an annular ledge **32** for supporting the face insert **14**. In a preferred embodiment, the body **12** is formed by investment casting a titanium alloy. With the face insert **14** in place, the club head **10** preferably defines a volume of at least 200 cc and more preferably a volume of at least 300 cc. The club head **10** has superior durability and club performance, including a coefficient of restitution (COR) of at least 0.79.

With reference to FIG. **3**, the composite region **16** of the face insert **14** is configured to have a relatively consistent distribution of reinforcement fibers across a cross section of its thickness to facilitate efficient distribution of impact forces and overall durability. The composite region **16** includes prepreg plies, each ply having a fiber reinforcement and a resin matrix selected to contribute to the club's durability and overall performance. Tests have demonstrated that composite regions formed of prepreg plies having a relatively low fiber areal weight (FAW) provide superior attributes in several areas, such as, impact resistance, durability and overall club performance. More particularly, FAW values below 100 g/m^2, or preferably 70 g/m^2 or more preferably 50 g/m^2, are considered to be particularly effective. Several prepreg plies having a low FAW can be stacked and still have a relatively uniform distribution of fiber across the thickness of the stacked plies. In contrast, at comparable resin content (R/C) levels, stacked plies of prepreg materials having a higher FAW tend to have more significant resin rich regions, particularly at the interfaces of adjacent plies, than stacked plies of lower FAW materials. It is believed that resin rich regions tend to inhibit the efficacy of the fiber reinforcement, particularly since the force resulting from golf ball impact is generally transverse to the orientation of the fibers of the fiber reinforcement. Preferred methods of manufacturing, which aid in reducing resin rich regions, are discussed in detail further below.

Due to the efficiency of prepreg plies of low FAW, the face insert **14** can be relatively thin, preferably less than about 4.5 mm and more preferably less than about 3.5 mm. Thus, use of the face insert **14** results in weight savings of about 10 g to 15 g over a comparable volume of metal used in the body **12** (e.g., Ti-6Al-4V). As mentioned above, this weight can be allocated to other areas of the club, as desired. Moreover, the club head **10** has demonstrated both superior durability and performance. In a durability test, the club head **10** survived over 3000 impacts of a golf ball shot at a velocity of about 44 m/sec. In a performance test of the club's COR, measured in accordance with the United States Golf Association Rule 4-1a, the club head had a COR of about 0.828.

With continued reference to FIG. **3**, each prepreg ply of the composite region **16** preferably has a quasi-isotropic fiber reinforcement, and the plies are stacked in a prescribed order and orientation. For convenience of reference, the orientation of the plies is measured from a horizontal axis of the club head's face plane to a line aligned with the fiber orientation of each ply. A first ply **20** of the composite region **16** is oriented at 0 degrees, followed by ten to twelve groups of plies (**22**, **24**, **26**) each having four plies oriented at 0, +45, 90 and −45 degrees, respectively. Thereafter, a ply **28** oriented at 90 degrees precedes the final or innermost ply **30** oriented at 0 degrees. In this embodiment, the first and final plies are formed of a prepreg material reinforced by glass fibers, such as 1080 glass fibers. The remaining plies are formed of prepreg material reinforced by carbon fiber.

A suitable carbon fiber reinforcement comprises a carbon fiber known as "34-700" fiber, available from Grafil, Inc., of Sacramento, Calif., which has a tensile modulus of 234 Gpa (34 Msi) and tensile strength of 4500 Mpa (650 Ksi). Another suitable fiber, also available from Grafil, Inc., is a carbon fiber known as "TR50S" fiber which has a tensile modulus of 240 Gpa (35 Msi) and tensile strength of 4900 Mpa (710 Ksi). Suitable epoxy resins known as Newport 301 and 350 are available from Newport Adhesives & Composites, Inc., of Irvine, Calif.

In a preferred embodiment, the composite region **16** includes prepreg sheets having a quasi-isotropic fiber reinforcement of 34-700 fiber having an areal weight of about 70 g/m^2 and impregnated with an epoxy resin (e.g., Newport 301) resulting in a resin content (R/C) of about 40%. For convenience of reference, the primary composition of a prepreg sheet can be specified in abbreviated form by identifying its fiber areal weight, type of fiber, e.g., 70 FAW 34-700. The abbreviated form can further identify the resin system and resin content, e.g., 70 FAW 34-700/301, R/C 40%. In a durability test, several plies of this material were configured in a composite region **16** having a thickness of about 3.7 mm. The resulting composite region **16** survived over 3000 impacts of a golf ball shot at a velocity of about 44 m/sec. In another preferred embodiment, the composite region **16** comprises prepreg plies of 50 FAW TR50S/350. This material was tested in a composite region **16** having a thickness of about 3.7 mm and it too survived a similar durability test.

With reference to FIG. **4**, the face insert **14** has sufficient structural strength that excessive reinforcement along the interface of the body **12** and the face insert **14** is not required, which further enhances beneficial weight allocation effects. In this embodiment, the body **12** is formed of a titanium alloy, Ti-6Al-4V; however, other suitable material can be used. The face insert **14** is supported by an annular ledge **32** and is secured preferably with an adhesive. The annular ledge **32** preferably has a thickness of about 1.5 mm and extends inwardly between about 3 mm to about 6 mm. The annular ledge **32** is sufficiently recessed to allow the face insert **14** to sit generally flush with a transition edge **34** of the body. Although, in this embodiment, the annular ledge **32** extends around the periphery of the front opening, it will be appreciated that other embodiments can utilize a plurality of spaced annular ledges, e.g., a plurality of tabs, to support the face insert **14**.

With continued reference to FIG. **4**, the metallic cap **18** of the face insert **14** includes a rim **36** about the periphery of the composite region **16**. In a preferred embodiment, the metallic cap **18** may be attached to a front surface of the face insert **14**, wherein the combined thickness of the prepreg plies of the face insert **14** and the metallic cap **18** are no greater than the depth D of the annular ledge **32** at the front opening of the body **12**. The rim **36** covers a side edge **38** of the composite region **16** to further protect against peeling and delamination of the plies. Preferably, the rim **36** has a height substantially the same as the thickness of the face insert **14**. In an alternative embodiment, the rim **36** may comprise a series of segments instead of a continuous cover over the side edge **38** of the composite region **16**. The metallic cap **18** and rim **36** may be formed, for example, by stamping or other methods known to those skilled in the art. A preferred thickness of the metallic cap **18** is less than about 0.5 mm, and more preferably, it is less than about 0.3 mm. However, in embodiments having a face insert **14** without a metallic cap **18**, weight savings of about 15 g can be realized.

Preferably, the thickness of the composite region **16** is about 4.5 mm or less and the thickness of the metallic cap **18** is about 0.5 mm or less. More preferably the thickness of the composite region **16** is about 3.5 mm or less and the thickness of the metallic cap **18** is about 0.3 mm or less. The metallic cap preferably comprises a titanium alloy.

Composite Material Process

The metallic cap **18** defines a striking face **40** having a plurality of grooves **42**. The metallic cap **18** further aids in resisting wear from repeated impacts with golf balls even when covered with sand. Preferably, a bond gap **44** of about 0.05 mm to 0.2 mm, and more preferably about 0.1 mm, is provided for adhesive attachment of the metallic cap **18** to the composite region **16**. In an alternative embodiment, the bond gap **44** may be no greater than 0.2 mm. The metallic cap **18** is preferably formed of Ti-6Al-4V titanium alloy; however, other titanium alloys or other materials having suitable characteristics can be employed. For example, a non-metallic cap, such as a cap comprising injection-molded plastic, having a density less than 5 g/cc and a hardness value of 80 Shore D may be employed.

As mentioned above, it is beneficial to have a composite region **16** that is relatively free of resin rich regions. To that end, fiber reinforcement sheets are impregnated with a controlled amount of resin to achieve a prescribed resin content. This is realized, in part, through management of the timing and environment in which the fiber sheets are cured and soaked.

The plies can be cut at least twice before achieving the desired dimensions. A preferred approach includes cutting plies to a first size, debulking the plies in two compression steps of about two minutes each. Thereafter, the plies are die cut to the desired shape, and compressed a third time; this time using a panel conformed to the desired bulge and roll. The plies are then stacked to a final thickness and compressed a fourth time with the conformed panel for about three minutes. The weight and thickness are measured preferably prior to the curing step.

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FIGS. **5-7** depict an effective soaking and curing profile for impregnating plies 70 FAW 34/700 fiber sheet with Newport 301 resin. Soaking and curing occurs in a tool having upper and lower plates. The tool is pre-layered with a mold release to facilitate removal of the composite material and is pre-heated to an initial temperature (T_1) of about 200° F. The initial soak period is for about 5 minutes, from t_0 to t_1. During the soak phase, the temperature and pressure remain relatively constant. The pressure (P_1) is at about 15 psi.

An alternative soaking and curing profile is depicted in FIGS. **8** and **9**. In this process, the temperature of the tool is initially about 200° F. (T_1) and upon placement of the composite material into the tool, the temperature is increased to about 270° F. (T_2). The temperature is then kept constant. The initial pressure (P_1) is about 20 psi. The initial soak period is for about 5 minutes, from t_0 (0 sec.) to t'_1. The pressure is then ramped up to about 200 psi (P_2). The post cure phase lasts about 15 minutes (t'_1 to t'_2) and a final soaking/curing cycle is performed at a pressure (P_1) of 20 psi for 20 minutes (t'_2 to t'_3).

Composite Face Roughness Treatment

In order to increase the surface roughness of the composite golf club face and to enhance bonding of adhesives used therewith, a layer of textured film can be placed on the material before curing. An example of the textured film is ordinary nylon fabric. Curing conditions do not degrade the fabric and an imprint of the fabric texture is transferred to the composite surface. Tests have shown that adhesion of urethane and epoxy, such as 3M® DP460, to the treated composite surface was greatly improved and superior to adhesion to a metallic surface, such as cast titanium alloy.

In order to increase the surface roughness of the composite region **16** and to enhance bonding of adhesives used therewith, a layer of textured film can be placed on the composite material before curing. An example of the textured film is ordinary nylon fabric. Curing conditions do not degrade the fabric and an imprint of the fabric texture is transferred to the composite surface. Tests have shown that adhesion of urethane and epoxy, such as 3M® DP460, to a composite surface treated in such a fashion was greatly improved and superior to adhesion to a metallic surface, such as cast titanium alloy.

A face insert **14** having increased surface roughness may comprise a layer of textured film co-cured with the plies of low FAW material, in which the layer of textured film forms a front surface of the face insert **14** instead of the metallic cap **18**. The layer of textured film preferably comprises nylon fabric. Without the metallic cap **18**, the mass of the face insert **14** is at least 15 grams less than a face insert of equivalent volume formed of the metallic material of the body **12** of the club head **10**.

Typically, adhesion of the 3M® DP460 adhesive to a cast metallic surface is greater than to an untreated composite surface. Consequently, when the face structure fails on impact, the adhesive peels off the composite surface but remains bonded to the metallic surface. After treating a composite surface as described above, the situation is reversed [–] and the 3M® DP460 peels off the metallic surface but remains bonded to the composite surface.

The enhanced adhesion properties of this treatment contribute to an improved fatigue life for a composite golf club face. In a test, a club head having an untreated face insert **14** and a COR of about 0.847 endured about 250 test shots before significant degradation or failure occurred. In contrast, a similar club head having a treated face insert **14** and a COR of about 0.842 endured over 2000 shots before significant degradation or failure occurred.

Alternatively, the means for applying the composite texture improvement may be incorporated into the mold surface. By doing so, the textured area can be more precisely controlled. For simple face plate joining to the opening of a cast body, the texture can be formed in surfaces where shear and peel are the dominant modes of failure.

It should be appreciated from the foregoing that the present invention provides a club head **10** having a composite face insert **14** attached to a metallic body **12**, forming a volume of at least 200 cc and providing superior durability and club performance. To that end, the face insert **14** comprises prepreg plies having a fiber areal weight (FAW) of less than 100 g/m^2. The face insert **14** preferably has a thickness less than 5 mm and has a mass at least 10 grams less than a face insert of equivalent volume formed of the metallic material of the body **12** of the club head **10**. The coefficient of restitution for the club head **10** is preferably at least 0.79.

Alternatively, the face insert **14** may comprise any non-metallic material having a density less than a metallic material of the body **12** along with a metallic cap **18** covering a front surface of the face insert **14** and having a rim **36**. For example, the face insert **14** of the present invention may comprise a composite material, such as a fiber-reinforced plastic or a chopped-fiber compound (e.g., bulk molded compound or sheet molded compound), or an injection-molded polymer either alone or in combination with prepreg plies having low FAW. The thickness of the face insert **14** may be substantially constant or it may comprise a variation of at least two thicknesses, one being measured at a geometric center and another measured near a periphery of the face insert **14**. In one embodiment, for example, an injection-molded polymer disk may be embedded in a central region of a plurality of low FAW prepreg plies. The total thickness of the face insert **14** may range between about 1 mm and about 8 mm, and preferably between about 2 mm and about 7 mm, more preferably between about 2.5 mm and about 4 mm, and most preferably between about 3 mm and about 4 mm.

In addition, the body **12** of a club head **10** in the present invention may be formed of a metallic material, a non-metallic material or a combination of materials, such as a steel skirt and sole with a composite crown, for example. Also, one or more weights may be located in or on the body **12**, as desired, to achieve final performance characteristics for the club head **10**.

FIG. **10**A illustrates a hollow iron golf club head **1000** including a heel **1002**, toe **1004**, sole portion **1008**, and top line portion **1006**. The striking face **1010** includes scoreline grooves **1012** that are designed for impact with the golf ball. The scorelines described in the embodiments herein can be molded into a composite face insert. In some embodiments, the golf club head **1000** body can be a single unitary cast piece that is adhesively attached to a striking face **1010** that is formed separately. In certain embodiments, the striking face **1010** is a composite insert as will be described in further detail below.

FIGS. **10**A and **10**B also show a center point **1001** being an ideal striking point in the center of the striking face **1010** and respective orthogonal center of gravity (hereinafter, "CG") axes. A CG x-axis **1005**, CG y-axis **1007**, and CG z-axis **1003** intersect at the center point **1001**. In addition, a CG z-up axis **1009** is defined as an axis perpendicular to the ground plane **1011** and having an origin at the ground plane **1011**. The ground plane **1011** is assumed to be a perfectly flat plane.

In certain embodiments, a desirable CG-x location is between about 5 mm (heel side) and about −5 mm (toe side) along the CG x-axis **1005**. A desirable CG-y location is between about 5 mm to about 20 mm along the CG y-axis **1007** toward the rear portion of the club head. Additionally, a desirable CG-z location is between about 12 mm to about 25 mm along the CG z-up axis **1009**, as previously described.

FIG. **10**B illustrates an elevated toe view of the golf club head **1000** including a back portion **1028**, a front portion **1030**, a sole portion **1008**, a top line portion **1006**, and a striking face **1010**, as previously described. The front surface of the striking face **1010** is contained within a face plane **1025**.

FIG. **11** illustrates a cross-sectional view according to one exemplary embodiment. The club head **1100** includes a back portion **1106**, a top line portion **1104**, a front portion **1102** and a sole portion **1108**. A composite striking face **1112** is located on the front portion **1102** of the body. In other words, the body includes a front opening that receives the composite striking face **1112**. After adhesively attaching the composite face **1112**, an interior cavity **1114** is formed. The club head **1100** back portion **1106** further includes a rear wall having an upper rear wall **1132** and a lower rear wall **1128**, and a sound and vibration dampening badge **1130**. The back portion **1106** also includes a rear protrusion **1124**, an upper edge **1126**, and a sole thickness **1122**.

FIG. **11** further shows the front opening of the club head body having a ledge **1134** extending around an entire periphery of the front opening of the body. It is understood that the ledge **1134** can be continuous or intermittently located around a periphery of the front opening. In one embodiment, the ledge **1134** is perpendicular to a front opening wall **1136**. In one embodiment, the ledge extends inwardly toward a center region of the face by a ledge distance **1118** of about 1 mm to about 5 mm, or about 3 mm to about 4 mm. Similarly, the front opening wall **1136** extends perpendicularly away from a plane of the striking face by a depth distance **1120** between about 1 mm to about 5 mm, or between 3 mm to about 4 mm.

In addition the striking insert **1112** includes a varying thickness and a thickened peripheral portion having a third thickness dimension **1110**. The composite insert **1112** includes a first thickness **1111** at the thinnest region of the striking insert **1112** and a second thickness **1116** located in a central region of the striking insert **1112**. The second thickness **1116** is the thickest dimension within the central region of the striking insert **1112**. In one embodiment, the second thickness **1116** is greater than the first thickness **1111** and less than the third thickness **1110** of the peripheral portion. The third thickness **1110** located in a peripheral portion of the striking insert **1112** is greater than both the second thickness **1116** and the first thickness **1111**. The peripheral region of the striking insert **1112** having the third thickness **1110** is attached to the ledge **1134**.

In one embodiment, the first thickness **1111** can be between about 1.5 mm and about 2.0 mm, with a preferred thickness of about 2 mm or less. The second thickness **1116** can be between about 2 mm and about 3 mm and the third thickness **1110** is between about 3 mm and about 4.5 mm, or preferably about 3.5 mm to about 4.0 mm.

Alternatively, variable thickness configurations or inverted cone configurations can be implemented in the striking face **1112** as discussed in U.S. Pat. Nos. 6,800,038, 6,824,475, 6,904,663, and 6,997,820, all incorporated herein by reference.

In the examples described herein, a composite face insert can have a striking surface area in a range of about 2,700 mm^2 to about 5,000 mm^2. The unsupported surface area (surface area on the rear surface of the striking insert that is not engaged with a supporting surface) of the composite face insert can be within a range of about 300 mm^2 to about 4,000 mm^2, or preferably 450 mm^2 to about 3,500 mm^2. In some embodiments, the unsupported surface area is at least greater than about 2,000 mm^2. The unsupported surface area is the portion of the composite insert that is defined by the first thickness **1111** and second thickness **1116** excluding the peripheral portion. The composite face thickness can be within a range of about 1 mm to about 8.0 mm, preferably about 2.5 to about 5 mm. In certain embodiments, the composite face thickness is less than about 4.0 mm. In embodiments having a thickened region, the thickened region surface area can range from about 230 mm^2 to about 2,000 mm^2.

FIG. **12** illustrates an alternative embodiment of a golf club head **1200** including a front portion **1202**, a rear portion **1206**, a sole portion **1208** and a top line portion **1204**. The club head **1200** includes a front opening located in the front portion **1202**. The club head **1200** further includes a composite striking insert **1216**, a gap cavity **1218**, a back wall **1214**, and a peripheral front opening wall **1210**. The composite striking insert **1216** includes a first thickness **1222**, a second thickness **1220**, and a third thickness **1224**. The third thickness **1224** corresponds to a thickened end portion **1212** of the striking insert **1216**.

The back wall **1214** includes a front engaging surface **1214***a* which provides support for the composite insert **1216** to be adhesively attached. The front engaging surface **1214***a* and the peripheral front opening wall **1210** create the front opening to receive the composite striking insert **1216**. The front engaging surface **1214***a* is offset from the front surface **1230** of the club head by an offset distance **1226**. The offset distance **1226** can be between about 1 mm and about 5 mm or preferably about 4 mm.

The offset distance **1226** is greater than or equal to the third thickness **1224** of the striking insert **1216** to enable the striking insert **1216** to sit within the front opening. The striking insert **1216** is located within the front opening so that the front striking insert **1216** surface is flush with the front portion surface **1230** of the club head body **1200**. The interior gap cavity **1218** is located between the striking insert **1216** and the front engaging surface **1214***a* of the back wall **1214** and can be about 0.1 cc to about 20 cc. In one embodiment, the interior cavity is less than about 10 cc.

The interior cavity is entirely defined and surrounded by the striking insert **1216** and the rear back wall **1214** only. The back wall **1214** is in direct adhesive contact with the striking insert **1216** and supports the striking insert **1216**. In other words, the thickened peripheral region **1212** of the striking insert is in direct contact with an interior surface of the back wall **1214**.

It is critical that the central region of the striking insert **1216** is not capable of making direct contact with the back wall **1214** upon impact with the golf ball to avoid unwanted sound and unwanted performance effects. Therefore, a critical distance **1228** of about 1 mm or more is maintained between the front engaging surface **1214***a* and a rear surface **1216***a* of the striking insert **1216** at a maximum second thickness **1220** location.

FIG. **13**A illustrates another exemplary embodiment according to another alternative embodiment of a golf club head **1300** including a front portion **1302**, a back portion **1306**, a sole portion **1308**, and a top line portion **1304**. The golf club head also includes a badge **1330**, back wall portion **1332**, an interior back wall surface **1328**, a protruding portion **1324**, an upper edge **1326**, a sole thickness **1320**, a ledge **1322**, a front opening wall **1310**, an interior cavity **1334**, and a striking insert **1312**. The ledge **1322** extends a distance **1316** inwardly and the front opening wall **1310** also extends a distance **1318** as previously described.

The striking insert material, of the embodiments described herein, are made of the processes and materials described above but can also be a composite material as described in U.S. patent application Ser. No. 10/831,496 (now U.S. Pat. No. 7,140,974), Ser. Nos. 11/642,310, 11/825,138, 11/998, 436, 11/823,638, 12/004,386, 12,004,387, 11/960,609, 11/960,610, and 12/156,947, which are incorporated herein by reference in their entirety. All of the composite inserts described herein can be made according to the processes and composite materials described within the above listed patents and patent applications. For example, in one embodiment, a composite face insert material having a fiber areal weight of less than 200 g/m^2 is utilized. In another embodiment, a face insert material has a fiber areal weight less than 100 g/m^2. In yet other embodiments, the face insert material has a fiber areal weight less than 150 g/m^2.

For example, water jet cutting can be utilized to cut the composite face inserts from a sheet of composite material as described in the patents and patent applications incorporated by reference. In addition, the face insert can be formed by CNC cutting

Some examples of composites that can be used to form the components include, without limitation, glass fiber reinforced polymers (GFRP), carbon fiber reinforced polymers (CFRP), metal matrix composites (MMC), ceramic matrix composites (CMC), and natural composites (e.g., wood composites). The face insert may also be made of a thermoplastic material, as described herein. In certain embodiments, the composite face inserts described herein are made of a material having a density less than about 1.5 g/cc.

FIG. **13**A shows a center cross-sectional view of the striking insert **1312** being a constant thickness **1314** (across the face of the striking insert **1312**) and the constant thickness **1314** being between about 3.0 mm to about 5.0 mm, or about 3.5 mm to about 4.5 mm.

FIG. **13**B is a detailed view of a lower portion of the golf club head **1300** shown in FIG. **13**A. FIG. **13**B shows a non-undercut design. Specifically, a lower leading edge zone **1346** of the club head body is completely filled with material and does not include an undercut or gap within the lower leading edge zone **1346** in a transition region between the striking surface of the club face and the sole portion **1308**.

FIG. **13**B shows a club face plane **1336** which contains the striking surface and is co-planar with the striking surface. Furthermore, the ledge **1322** includes a front engaging surface **1344** that is contained within a ledge plane **1338**. The club face plane **1336** and the ledge plane **1338** are substantially parallel with respect to one another. A segment **1342** of the sole portion **1308** is located between the face plane **1336** and the ledge plane **1338**.

The lower leading edge zone **1346** is defined by the front opening wall **1310**, the ledge plane **1338**, the club face plane **1336**, and the sole portion segment **1342**. Within the lower leading edge zone **1346**, an undercut or gap is avoided in order to lower the first leading edge groove centerline axis **1348** with respect to the ground **1301**. The leading edge groove centerline axis **1348** is defined as the intersection of a bisectional plane **1352** and the club face plane **1336** at the centerline axis **1348** shown in FIG. **13**B.

A low leading edge groove centerline axis **1348** is beneficial in allowing a golfer to make engaging contact with a ball sooner upon impact. In addition, a lower leading edge groove centerline axis **1348** may have additional benefits when a golfer mis-hits a ball by improving the quality of contact between the ball and the leading groove or lowest groove.

A horizontal plane **1350** contains the leading edge groove centerline axis **1348** and is parallel with the ground surface **1301**. The height distance, h, between the horizontal plane **1350** of the leading edge groove axis **1348** and the ground surface **1301** is between about 4 mm and about 10 mm. In certain embodiments, the height distance, h, is between about 4 mm and about 8 mm or between about 4 mm and about 6 mm.

FIG. **14**A illustrates a magnified view **1400** of the junction between a composite face insert **1404** and a ledge **1418**, according to one exemplary embodiment. The composite face insert **1404** includes an end wall **1410** and a rear surface wall **1412**. The composite face insert **1404** is attached to a front opening wall **1408** and front ledge surface **1406** by an adhesive **1414**. The adhesive **1414** is applied over a majority of the interface between the composite face insert **1404** and the front opening wall **1408** and front ledge surface **1406**.

The front ledge surface **1406** intersects with the front opening wall **1408** at a rounded corner location **1416**. The corner **1416** includes a radius of between about 0.1 mm and about 0.5 mm. In certain embodiments, the radius is at least about 0.30 mm or greater. A larger corner **1416** radius will avoid high stress concentrations that may result in material failure of the ledge **1418** after repeated use.

The rear bond gap distance, x, is located between the front ledge surface **1406** and the rear surface wall **1412**. The rear bond gap distance, x, is measured along an axis that is perpendicular to the face plane toward a rear portion of the club head.

The side bond gap distance **1402** between the end wall **1410** and the front opening wall **1408** is between 0.1 mm and 0.5 mm, or about 0.3 mm or less. In one embodiment, the side bond gap distance **1402** and the rear bond gap distance, x, are filled with an adhesive epoxy to attach the composite insert **1404**.

In certain embodiments, the rear bond gap distance, x, is equal to or greater than the side bond gap distance **1402**. In some embodiments, the rear bond gap distance, x, is in accordance with the following inequality:

$$x \geq 0.2 \text{ mm} \qquad \text{Eq. 1}$$

In the above inequality, the side bond gap distance **1402** is set at a distance of about 0.2 mm. If the rear bond gap distance, x, follows the inequality of Equation 1 described above, the composite face insert **1404** will be securely attached within the front opening. Without maintaining a rear bond gap distance, x, larger than the side bond gap distance **1402**, the composite face insert **1404** may become loose after repeated impacts and bending.

FIG. **14**A also shows a metallic cap **1420** which can be implemented in any of the embodiments described herein. The metallic cap **1420** can be made of a material having a density less than 9 g/cc or less than 5 g/cc such as a titanium alloy, CP titanium, or a nickel based alloy. In addition, the metallic cap **1420** can be a Ni—Cr or Co—Ni alloy with a chrome plated layer formed by electro-plating or electro-forming.

FIG. **14**B further shows another embodiment similar to FIG. **14**A except the metallic cap **1420** is replaced by a polymer or polyurethane front layer **1421** having grooves incorporated thereon. The polymer or polyurethane material can be of the type described in U.S. patent application Ser. No. 11/960,609, already incorporated by reference in its entirety. Both the metallic cap **1420** and polymer or polyurethane layer **1421** cover the entire front surface of the face insert **1404**.

FIG. **15**A illustrates an alternative embodiment **1500** including a composite face insert **1504**, a ledge **1518**, an end wall **1510**, a rear surface wall **1512**, a front opening wall **1508**, front ledge surface **1506**, an adhesive **1514** and a corner **1516**, as previously described. The face insert **1504** can include a metallic cap or polyurethane cover as previously described.

However, the embodiment shown in FIG. **15**A includes an additional step gap **1522** in addition to a side bond gap distance **1502** or bond gap. The side bond gap distance **1502** and the step gap **1522** (measured along an axis parallel to the face plane) create a total engineering gap **1520**. The step gap **1522** is created by a step region **1524**. The step region **1524** and step gap **1522** are present about the entire circumference of the front opening wall **1508**.

As shown, the side bond gap **1502** and step gap **1522** are filled with the adhesive **1514**. The adhesive **1514** in the front portion parallel with the face plane to avoid unwanted bumps or sharp edges on the striking face.

In one embodiment, the total engineering gap **1520** is about 0.5 mm and the side bond gap distance **1502** is about 0.2 mm. As a result, the step gap **1522** is about 0.3 mm. The total engineering gap **1520** can be between about 0.2 mm and about 1 mm or preferably between about 0.2 mm and about 0.8 mm.

The engineering gap **1520** enables the composite face insert **1504** to be attached without maintaining a perfect side bond gap distance **1502** about the entire circumference of the face insert **1504**. For example, the embodiment of FIGS. **14**A and **14**B, without a step gap and engineering gap would require the exact placement of the composite face insert centered within the front opening to achieve a consistent side bond gap distance. An inconsistent side bond gap distance, without an engineering gap, would be clearly seen by the user and would have a negative impact on aesthetic appeal and performance parameters. In other words, the composite face insert without an engineering gap may look off-center to the golfer and negatively impact the golfer's performance.

FIG. **15**B is a front view of a composite face insert with an engineering gap **1520**. The side bond gap distance **1502** and step gap **1522** are also shown. Within the face plane, the engineering gap **1520**, the side bond gap distance **1502**, and the step gap **1522** are measured along an axis that is perpendicular to the end wall **1510** at any given point along the outer peripheral edge of the composite face insert **1504** (within the face plane). The front opening wall **1508** is shown in dashed lines from a front perspective.

The above described engineering gap distance, side bond gap distance and step gap distance can be applied to any of the embodiments described herein. It is understood that the gaps shown in FIG. **15**B are exaggerated for clarity.

FIGS. **16-18** illustrate similar embodiments to FIGS. **11-13**B, having similar features except the club heads are filled with a filler material.

FIG. **16** illustrates a cross sectional view of an alternative embodiment of a golf club head **1600**. The cross section is taken through an ideal striking point in the center of the striking face as previously described.

The club head **1600** includes a front portion **1602**, back portion **1606**, a top line portion **1604**, and a sole portion **1608**. The club head **1600** further includes an upper back wall **1632**, a lower back wall **1628**, a badge **1630**, a sole thickness **1622**, a rear protrusion **1624**, and filler material **1614**. The badge **1630** is positioned above an upper edge **1626** and covers an aperture **1638** used for introducing the plug **1640** and filler material **1614** into the interior cavity of the club head **1600**. The filler material **1614** and plug **1640** can be of the same configuration, material, and keying design as described in U.S. patent application Ser. No. 12/462,198, incorporated by reference herein, in its entirety.

FIG. **16** further shows a front opening wall **1636**, a ledge distance **1618**, a depth distance **1620**, a first thickness **1611**, a second thickness **1616**, a third thickness **1610**, a ledge **1634**, and a composite face insert **1612**, previously described.

In one embodiment, the filler material can be an expandable foam such as Expancel® 920 DU 40 which is an acrylic copolymer encapsulating a blowing agent, such as isopentane. A copolymer is greater than about 75 weight percent of the composition and the blowing agent is about 15-20 weight percent. The unexpanded particle size of the filler material can be between about 2 μm and about 90 μm depending on the context.

In one embodiment, the density of the filler material is between about 0.16 g/cc and about 0.19 g/cc. In certain embodiments, the density of the filler material is in the range of about 0.03 g/cc to about 0.2 g/cc, or about 0.04-0.10 g/cc. The density of the filler material impacts the COR, durability, strength, and filling capacity. In general, a lower density material will have less of an impact on the COR of a club head. The filler material can have a hardness range of about 15-85 Shore OO hardness or about 80 Shore OO hardness or less.

In one embodiment, the filler material is subject to heat for expansion of about 150° C.+/−10° C. for about 30 minutes. In some embodiments, the expansion of the filler material can begin at about 125° C. to about 140° C. A maximum expansion temperature range can be between about 160° C. to about 190° C. The temperature at which the expansion of the filler material begins is critical in preventing unwanted expansion after the club head is assembled. For example, a filler material that begins expanding at about 120° C. will not cause unwanted expansion when the club is placed in the trunk of a car (where temperatures can reach up to about 83° C.). Thus, a filler material that has a beginning expansion temperature of greater than about 80° C. is preferred.

Some other examples of materials that can be used as a filler material or plug material include, without limitation: viscoelastic elastomers; vinyl copolymers with or without inorganic fillers; polyvinyl acetate with or without mineral fillers such as barium sulfate; acrylics; polyesters; polyurethanes; polyethers; polyamides; polybutadienes; polystyrenes; polyisoprenes; polyethylenes; polyolefins; styrene/isoprene block copolymers; metallized polyesters; metallized acrylics; epoxies; epoxy and graphite composites; natural and synthetic rubbers; piezoelectric ceramics; thermoset and thermoplastic rubbers; foamed polymers; ionomers; low-density fiber glass; bitumen; silicone; and mixtures thereof. The metallized polyesters and acrylics can comprise aluminum as the metal. Commercially available materials include resilient polymeric materials such as Scotchdamp™ from 3M, Sorbothane® from Sorbothane, Inc., DYAD® and GP® from Soundcoat Company Inc., Dynamat® from Dynamat Control of North America, Inc., NoViFlex™ Sylomer® from Pole Star Maritime Group, LLC, Isoplast® from The Dow Chemical Company, and Legetolex™ from Piqua Technologies, Inc. In one embodiment the filler material may have a modulus of elasticity ranging from about 0.001 GPa to about 25 GPa, and a durometer ranging from about 5 to about 95 on a Shore D scale. In other examples, gels or liquids can be used, and softer materials which are better characterized on a Shore A or other scale can be used. The Shore D hardness on a polymer is measured in accordance with the ASTM (American Society for Testing and Materials) test D2240.

In certain embodiments, the interior cavity of the club head **1600** can includes the plug **1640** for absorbing vibration. It is understood, that an embodiment without the plug **1640** is within the scope of the present description.

After the plug **1640** is frictionally engaged in a position, the filler material **1614** can be inserted into the cavity. In certain embodiments, the plug **1640** is a polymeric material.

In one embodiment, the plug **1640** material is a urethane or silicone material having a density of about 0.95 g/cc to about 1.75 g/cc, or about 1 g/cc. The plug **1640** can have a hardness of about 10 to about 70 shore A hardness. In certain embodiments, a shore A hardness of about 40 or less is preferred.

The filler material **1614** can be an expanding foam material that is expanded by a certain amount of heat as previously described. The filler material **1614** expands and fills a relatively large volume, greater than the volume occupied by the plug **1640**.

In some embodiments, the volume of the cavity is between about 1 cc and about 200 cc, or preferably between about 10 cc and about 20 cc. For the purposes of measuring the cavity volume herein, the aperture **1638** is assumed to be removed from the back wall **1632** and an imaginary continuous back wall or substantially planar back wall is utilized to calculate the cavity volume.

In some embodiments, the filler material **1614** occupies about 50% to about 99% of the total club head cavity volume while the plug **1640** occupies between about 0% to about 20% of the total cavity volume. In specific embodiments, the plug **1640** occupies between about 0.1 cc and 1 cc with the remainder of the cavity volume being filled by the filler material **1614**. It is understood that any of the embodiments described herein can be provided without a plug and filler material.

In order to achieve a desirable CG location, the filler material **1614** and plug **1640** must be lightweight. In certain embodiments, the total mass of the filler material **1614** and plug **1640** is less than about 5 g or between about 2 g and about 4 g. In one embodiment, the total weight of the filler material **1614** and the plug **1640** is 10 g or less or about 3 g or less. In certain embodiments, the total weight of the filler material **714** and plug **1640** is less than 2% of the total weight of the club head **1600** (excluding any badges, filler material/plug, and ferrule ring). In other embodiments, the total weight of the filler material **714** and plug **1640** is less than about 10% of the total weight of the club head **1600**.

In some embodiments, the total weight of the filler material **1614** and plug **1640** is between about 1% and about 5% of the total weight of the club head (excluding the badges, filler material/plug, and ferrule ring). Thus, a desirable CG location is still attainable while improving the sound and feel of the golf club head. In certain embodiments, the plug **1640** can weigh about 0.5 g to about 1 g and the filler material **1614** can weigh about 5 grams or less. In some embodiments, the plug **1640** weighs about 0.7 g or less. In other embodiments, the plug **1640** can be equal to or heavier than the total filler material weight.

In yet other embodiments, the filler material **1614** and the plug **1640** have a combined weight of less than 20% of the total club head weight (excluding badges, filler material/plug, and ferrule ring). In one embodiment, the combined weight of the filler material **1614** and plug **1640** is less than 5%.

FIG. **17** illustrates an alternative embodiment of a golf club head **1700** including a front portion **1702**, a rear portion **1706**, a sole portion **1708** and a top line portion **1704**. The club head **1700** includes a front opening located in the front portion **1702**. The club head **1700** further includes a composite striking insert **1716**, filler material **1718**, a back wall **1714**, and a peripheral front opening wall **1710**. It is possible to include a plug, badge, and aperture as described above. The striking insert **1716** includes a first thickness **1722**, a second thickness **1720**, and a third thickness **1724**. A critical distance **1728** having dimensions described above is also present. The peripheral region **1712** is in contact with the front surface of the rear wall **1714**. The front surface of the rear wall **1714** is located at an offset distance **1726**, previously described.

The filler material **1718** can be of the type already described above or can be a thermoplastic elastomer having a density of about 0.9 g/cc to about 1.20 g/cc.

FIG. **18** shows a top line portion **1804**, back portion **1806**, front portion **1802**, sole portion **1808**, back wall portion **1832**, badge **1830**, interior back wall surface **1828**, upper edge **1826**, protruding portion **1824**, ledge **1822**, sole thickness **1820**, offset distance **1818**, ledge distance **1816**, constant face thickness **1814**, front opening wall **1810**, and filler material **1834**, as previously described.

In certain embodiments, the badges and composite face inserts, described herein, can be adhesively attached with epoxy or any known adhesive. For example, an epoxy such as 3M® DP460 can be used. It is possible for the badge **1830** to be mechanically attached to the back portion **1806** of the club head **1800**.

After the hollow iron **1800** is filled with the filler material **1834**, the badge **1830** is adhesively or mechanically attached to the back wall **1832** to cover or occlude the aperture to prevent filler material from leaving the cavity and also to achieve a desired aesthetic and while creating further dampening.

In some embodiments, the COR is greater than about 0.790. Preferably, the COR is at least 0.80 as measured according to the USGA Rules of Golf based on a 160 ft./s ball speed test and the USGA calibration plate. The COR can even be as high as 0.83.

In one embodiment, the body portion is made from 17-4 steel. However another material such as carbon steel (e.g., 1020, 1030, 8620, or 1040 carbon steel), chrome-molybdenum steel (e.g., 4140 Cr—Mo steel), Ni—Cr—Mo steel (e.g., 8620 Ni—Cr—Mo steel), or austenitic stainless steel (e.g., 304, N50, or N60 stainless steel, 410 stainless steel) can be used.

The components of the described components disclosed in the present specification can be formed from any of various suitable metals or metal alloys.

In addition to those noted above, some examples of metals and metal alloys that can be used to form the components of the parts described include, without limitation: titanium alloys (e.g., 3-2.5, 6-4, SP700, 15-3-3-3, 10-2-3, or other alpha/near alpha, alpha-beta, and beta/near beta titanium alloys), aluminum/aluminum alloys (e.g., 3000 series alloys, 5000 series alloys, 6000 series alloys, such as 6061-T6, and 7000 series alloys, such as 7075), magnesium alloys, copper alloys, and nickel alloys.

The body portion can include various features such as weighting elements, cartridges, and/or inserts or applied bodies as used for CG placement, vibration control or damping, or acoustic control or damping. For example, U.S. Pat. No. 6,811,496, incorporated herein by reference in its entirety, discloses the attachment of mass altering pins or cartridge weighting elements.

FIG. **19** shows a golf club head **1900** having a heel **1902**, toe portion **1904**, sole portion **1908**, top line portion **1906**, striking face **1910**, scoreline grooves **1912**, a center point **1901**, a CG x-axis **1905**, a CG z-axis **1903**, a CG z-up axis, a ground plane **1911** as previously described in FIG. **10**A.

However, the composite face insert **1916** does not extend across the striking surface to a toe portion **1904** edge **1920** as shown in FIG. **19**. The composite face insert **1916** occupies about 50% to about 90% of the front striking surface plane. Subsequently, about 50% to about 10% of the front striking surface plane is comprised of the metallic material similar to the golf club head body.

Including a smaller percentage of composite face insert **1916** striking surface area can result in a significant reduction in manufacturing cost and composite material savings.

At least one advantage of the present invention is that a lightweight composite face insert will provide an improved CG club head location.

In addition, a certain engineering gap can be utilized to reduce the manufacturing time and expense associated with perfectly centering a composite face insert in a front opening of the golf club head.

At least another advantage of the embodiments described above, is that a rear back wall and badge can act to create an enclosed cavity behind the composite face so that the ledge and adhesive material used to bond the face insert to the club body is not visible to the user.

At least another advantage of the embodiments described is that a lightweight filler material arrangement is created allowing the center of gravity of the hollow iron construction to remain low while improving the sound and feel of the club during use.

The embodiments described herein conform with the USGA (United States Golf Association) Rules of Golf and Appendix II, 5c related to the Determination of Groove Conformance (issued in August 2008). For example, clubs having a loft of 25 degrees or higher meets the groove width, groove depth, groove separation, groove consistency, area limitations, and edge radius requirements set forth by the USGA. In the embodiments described herein, less than 50% of measured values of Area/(Width+Separation) are greater than 0.0030 in^2/in and no single measured value of Area/(Width+Separation) value for any single groove is greater than 0.0032 in^2/in.

With respect to a groove edge radius, the groove edges are in the form of a radius having an effective radius not less than 0.010" as described by the two circles method described in the USGA rules. In addition, the effective radius is not greater than 0.020". In the embodiments described, less than 50% of the upper groove edges or lower groove edges fails the two circles method subject to a 10 degree angular allowance as described in the USGA rules. No single groove edge protrudes more than 0.0003" outside the outer circle.

In view of the many possible embodiments to which the principles of the disclosed invention may be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the invention as set forth. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

We claim:

1. An iron-type golf club head comprising:

a body having a heel portion, a sole portion, a toe portion, a top-line portion, a front portion, a rear portion, and a striking face;

a cavity being defined by at least a rear surface of the striking face, an interior rear wall surface arranged behind the rear surface of the striking face, and the sole portion;

a composite face insert comprising prepreg plies having a fiber areal weight of less than 200 g/m^2, the face insert being attached at a front opening of the body and enclosing the front opening of the body, wherein the thickness of the prepreg plies is within a range of about 1 mm to about 8 mm; and

wherein the composite face insert includes a front striking surface having a polyurethane layer that is located on a majority of the front striking surface of the composite face insert,

wherein the body includes a lower leading edge zone that is entirely filled with material.

2. The iron-type golf club head of claim **1**, wherein the interior rear wall in the rear portion encloses a substantial portion of the rear portion to create a substantially enclosed cavity.

3. The iron-type golf club head of claim **1**, wherein the composite face insert includes a front striking surface having a metallic cap layer that is located on a majority of the front striking surface of the composite face insert.

4. The iron-type golf club head of claim **1**, wherein a height distance between a horizontal plane of the leading edge groove location and the ground surface is between about 4 mm and about 10 mm.

5. The iron-type golf club head of claim **1**, wherein a height distance between a horizontal plane of the leading edge groove location and the ground surface is between about 2 mm and about 6 mm.

6. The iron-type golf club head of claim **1**, wherein the composite face insert includes a thickened central region.

7. The iron-type golf club head of claim **1**, wherein the coefficient of restitution is at least 0.79.

8. The iron-type golf club head of claim **1**, wherein at least one plug is positioned to be in contact with at least a portion of the face insert.

9. The iron-type golf club head of claim **1**, wherein at least one plug contacts the inner back wall surface.

10. The iron-type golf club head of claim **1**, further comprising an aperture into the enclosed cavity, the aperture being configured to allow the cavity to be filled with a filler material.

11. The iron-type golf club head of claim **10**, wherein the filler material is an expanding foam material having a density between about 0.03 g/cc and about 0.2 g/cc.

12. The iron-type golf club head of claim **1**, wherein a rear bond gap distance is equal to or greater than a side bond gap distance.

13. The iron-type golf club head of claim **1**, wherein a rear bond gap distance is greater than or equal to 0.2 mm.

14. The iron-type golf club head of claim **1**, wherein a front ledge surface and front opening wall intersect at a rounded corner location.

15. The iron-type golf club head of claim **1**, wherein at least one scoreline is molded into the composite face insert.

16. The iron-type golf club head of claim **1**, wherein the composite face insert is formed by water jet cutting.

17. The iron-type golf club head of claim **1**, wherein the composite face insert includes prepreg plies having a fiber areal weight of less than 150 g/m^2.

18. An iron-type golf club head comprising:

a body having a heel portion, a sole portion, a toe portion, a top-line portion, a front portion, a rear portion, and a striking face;

a cavity being defined by at least a rear surface of the striking face, an interior rear wall surface substantially facing the rear surface of the striking face, and the sole portion;

a composite face insert comprising prepreg plies having a fiber areal weight less than 100 g/m^2, the face insert being attached at a front opening of the body and enclosing the front opening of the body, wherein the thickness of the prepreg plies is within a range of about 1 mm to about 8 mm, the golf club head having a coefficient of restitution of at least 0.79.

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